EFFECTS OF MOWING AND FERTILIZATION ON WARM SEASON TURFGRASSES

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Abstract

The need to maintain good quality turfgrass at relatively low costs in the face of current energy crisis and inflationary costs have led to the investigations reported in this thesis. A field experiment was conducted to investigate the effect of mowing heights and N fertilization on the commonly cultivated warm season grasses used in the tropics and subtropics. Response trends of zoysiagrass (Zoysia japonica Steud.) and seashore paspalum (Paspalum vaginatum Swartz) were also observed.

A greenhouse experiment was conducted to determine the N-K levels required of carpetgrass (Axonopus affinis Chase) which is the main turfgrass used in Singapore for parks and open spaces. The objective of this experiment was to determine the optimum N-K combination required to produce acceptable turf at lowest input.

Three nitrogen fertilizer levels and two mowing heights were used in the field experiment. N levels were recommended low, medium, and high for the individual turf species. Growth parameters used for evaluation of responses were visual ratings, clipping dry weights, and

chlorophyll contents in both experiments. In addition, root depths were measured for the field experiment and dried shoots and roots were weighed at the termination of the glasshouse pot culture experiment. Tissue N analysis was carried out to relate the growth responses observed.

Mowing heights affected visual ratings of all turf species. However, they differ in response to mowing height in that bermudagrass (Cynodon dactylon (L.) Pers.) and centipedegrass (Eremochloa ophiuroides (Munro.) Hack.) had higher visual ratings at low mowing height whilst carpetgrass (Axonopus affinis Chase) and St. Augustinegrass (Stenotaphrum secundatum (Walt.) Kuntze) had higher visual ratings at high mowing heights. Mowing heights had different effects on different grasses in terms of clipping dry weights. The method of collecting clippings was less than desirable and led to higher experimental error for some grasses than others. Chlorophyll contents followed the same trend as visual ratings in that bermudagrass and centipedegrass had higher chlorophyll content at low mowing heights whilst centipedegrass and St. Augustinegrass were higher at high mowing heights. Root depths of St. Augustinegrass decreased significantly at low mowing height. The root depths of all other species tended to decrease with closer mowing although the effect was not significant at the 5% level.

Centipedegrass was the only species that responded to N fertilizer as expected. Clipping dry weights, chlorophyll contents, and %N increased with increasing levels of N. Rooth depth decreased as N level increased. The reason for lack of response of other species to N fertilizer was probably due to insufficient differences in N levels applied.

In the glasshouse experiment, increasing N levels from 6.25 ppm to 50 ppm, increased visual ratings, clipping dry weights, and chlorophyll contents, and depressed root growth. N has no effect on shoot dry weights at termination of the experiment. Average results over the experimental period showed that K had no effect on visual ratings, shoot dry weights, and root dry weights. The optimum level for K for maximum chlorophyll content was 15 ppm whereas clipping dry weights increased with increasing K above 15 ppm. Combinations within the range of 25 ppm N with 15 ppm K and 25 ppm N with 30 ppm K produced good quality carpetgrass without being over luxuriant. However, as this was based on data collected from a glasshouse experiment, it should be further tested in the field.

Visual ratings was found to be a reliable parameter for evaluation of turfgrass quality, and should suffice for routine purposes. Visual ratings were correlated with clipping dry weights, chlorophyll contents, and root dry weights.

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CHAPTER I

INTRODUCTION

Turfgrass is an integral part of the man-made environment and becomes increasingly important as quality of life is emphasized. It is widely cultivated for its many functional and recreational uses. In contrast to crop production, where plant quality and yield are of major importance, turfgrass culture is primarily concerned with its utilitarian and aesthetic qualities. While these are determined, in part, by the inherent potentials of the individual species and cultivars, they are influenced by the interaction of many factors, including soil water, fertilization, and mowing frequency and height.

The cultural requirements of turfgrasses have made their maintenance very costly. Maintenance of turf has been said to be an energy sink (Busey and Burt 1979). It has been reported that the maintenance budget for turfgrass on the island of Oahu in 1975 was about $7 million (Van Dam and Murdoch 1975). $450 million was spent in Florida in 1974 to maintain established turf (Busey and Burt 1979). In the same report, Busey and Burt (1979) estimated the annual management costs for $93m^2$ of various turf species. Hybrid bermudagrass (Cynodon dactylon x C. transvaalensis Burtt-Davey) costs \$70, zoysiagrass and St. Augustinegrass \$35, and centipedegrass \$15. With ever-increasing costs of labour and energy, it is all the more important that cultural practices adopted by turf managers be efficient. Thus, it is of pragmatic importance for turfgrass managers and researchers to know the response of turfgrass to different cultural regimes and plan the management strategy. Beard (1975) similarly stated the need to develop turfgrasses and cultural techniques suitable for the future changes in the types and intensity of use of turfs resulting from increasing populations and demands for non-renewable resources and food.

Many cultural studies have been conducted on cool season grasses, but records of such studies on warm season grasses (except hybrid bermudagrass) have been rather scarce. Two important cultural practices: mowing and fertilization were selected for the present study on the management of warm season turfgrasses.

Mowing is a fundamental practice unique to turfgrass culture (Beard 1973). It is the means by which the uniformity of the turf surface is attained for ornamental beautification and for the many sports and recreational activities. As it is a defoliation process, it affects the physiological, developmental and growth responses of the turfgrass. Mowing heights have to be monitored so that the quantity of leaf tissue removed will not be detrimental to the turfgrass, while achieving the purpose for which the turf is intended. It has been found that mowing heights influenced the growth habit and water consumption of C_3 turfgrass plants (Biran et al 1981). The mowing heights tolerated and recommended vary from species to species and cultivar to cultivar. The turfgrasses with bunched growth habit generally do not tolerate lower cuts as well as those with creeping habit (Beard 1973).

The fertilization program is an inherent part of turfgrass management. Although the triad, N-P-K, is commonly applied, nitrogen (N) is the nutrient that most frequently controls growth. It is not only a dominant factor in controlling shoot growth, but also the balance between root and shoot growth (Adams 1980). Nitrogen is also required in the largest quantity of all the macronutrients. On the other hand, potassium (K) may not affect any visual response, however, its importance cannot be underestimated. Turfgrasses also require K in relatively large amounts, second only to N for proper growth and development (Knoop 1972). The N-K balance also appeared to effect growth responses (Monroe et al 1969). Phosphorus (P) is required in small quantities. Because of the important roles of N and K on turf quality, the effects of N and its interactions with mowing heights on warm season turfgrasses, and N-K effects on the commonly grown turfgrass of the humid tropics, namely carpetgrass (*Axonopus affinis* Chase) were studied in the present investigation.

Evaluation of turfgrass quality is a highly subjective appraisal, characterized by spurious results. One observer may consider the condition of a given area satisfactory, while another may have a different opinion (Mantell and Stanhill 1966). Ideally, an objective method of appraisal which is convenient for recommending cultural practices should be used. Waddington et al (1964) cited many qualitative and quantitative methods such as measurements of clipping yield, root growth and distribution, plant height, population density, chlorophyll content, and visual ratings of color and general appearance. To circumvent limitations of some of the evaluation methods, such as personal biasness, and to obtain a better and more objective indication of plant nutrition-related problems, tissue analysis has been found to be an useful analytical tool.

In the present study, a number of methods were employed simultaneously in the assessment of the various treatment effects: visual ratings, chlorophyll content, clipping dry weight, root dry weight and depth, and tissue analysis. The extent to which these individual methods are correlated was then determined.

In view of the demand for high quality turfgrass and the ever-increasing costs of maintenance and repair of turfed areas, the goal of this investigation was to determine the following:

1) Responses, in respect of visual rating, chlorophyll content, clipping dry weight, root depth, and tissue analysis, of warm season turfgrasses to mowing heights and N fertilization.

2) Efficient maintenance practices in respect

mowing heights and N fertilization.

3) The response of carpetgrass (*Axonopus affinis* Chase) to N-K treatment.

4) The correlation of the various evaluation methods and their usefulness in routine evaluation of turfgrass quality.

CHAPTER II

LITERATURE REVIEW

Morgan (1969) stated that the "approach to programming turfgrass management is to provide optimum root development, vigorous top growth without excessive succulence, reduced mowing and thatch development, minimum disease potential, and reduced irrigation requirements while maintaining desired beauty".

Cultural treatments can influence the species composition of turf. Taylor (1974) recorded an increase of bentgrass invasion in turf containing Kentucky bluegrass and red fescue at low mowing heights. Similarly, 'Merion' bluegrass in mixture with creeping red fescue was found to predominate under high level of nitrogen; while creeping red fescue predominated when maintained at a low level of nitrogen (Juska et al 1955). Numerous works have been conducted, especially with cool season grasses, to better understand their reactions to different cultural practices in order to attain the above goal.

Quality of turfgrass is influenced by the nutritional status of the plant such as, availability and quantity of nonstructural carbohydrates, formation of proteins and accumulation of nutrients. Many interacting factors modify this, including cultural variables such as mowing height and frequency, and rates of N and K fertilization, (Adams et al 1974, Keisling et al 1980, Wagner 1967, and Watschke and Waddington 1974).

Nitrogen

Any essential plant nutrient may control growth and development but N is the most important nutrient in the majority of cases in turf culture and it is upon this that most work has centered. Besides carbon, hydrogen and oxygen, turfgrasses require N in the largest amount of the essential nutrients. It is a constituent of molecules vitally important in turfgrass growth and development, namely:

1) The chlorophyll molecule which is involved in photosynthesis.

2) Amino acids and proteins, a major portion of the protoplasm.

3) Nucleic acids which are responsible for hereditary transfer of plant characteristics.

4) Enzymes and vitamins which catalyze metabolic processes within the plant.

Turfgrasses normally contain from 3 to 6% N on a dry matter basis if there is no soil N deficiency (Beard 1973). Deficiency symptoms were reported when N tissue level dropped below 2.25% (Menn 1970). However, in Tifdwarf bermudagrass, Fujimoto (1979) could see noticeable deficiency symptoms as the tissue concentration dropped below 4%.

Nitrogen nutrition can effect 1) the shoot growth; 2) the root growth; 3) shoot density; 4) color; 5) disease proneness; 6) heat, cold and drought hardiness; 7) recuperative potential; and composition of the turfgrass community (Beard 1973).

In general, elevating N supply increases top growth and depresses root growth. Past researchers have demonstrated this relationship. Among them were works by Adams et al (1974) on bluegrass and creeping bentgrass, Eckhardt and Johnson (1976) on bentgrass, Goss and Law

(1967) on bluegrass, Juska et al (1955) on 'Merion' bluegrass, Madison (1962) on 'Seaside' and 'Highland' bentgrass, Oswalt et al (1959) on bromegrass and orchardgrass, and Sullivan (1961) on Kentucky bluegrass blend.

N also promotes tillering, increases verdure and yield and improves color of turf (Juska and Murray 1974, and Madison 1962). However, Adams et al (1974) found that tillering in bluegrass and ryegrass began to decline before overall top growth with increasing N levels. N controls the balance between shoot growth and root growth. Oswalt et al (1959) found that when N was used, shoot-root ratio was wider. This effect is, however, not constant but depends on the physiological age and other environmental conditions. Different grasses have different N requirement and optimum growth is influenced by the balance between N, P and K fertilization (Volk and Horn 1974). Low shoot production is undersirable as turfgrass must have sufficient new growth to overcome abuse through traffic wear and also present a desirable appearance.

The balance between shoot and root is a most important factor in the consideration of plant growth.

For maximum turf quality, Goss and Law (1967) suggested a shoot root ratio of 6 or 7 : 1. A narrow ratio is preferred for turfgrass unless it becomes too narrow because of inadequate shoot production. Similarly, apparent photosynthesis of C_3 tall fescue (Festuca arundinacea Schrels.) and C_4 Panicum maximum Jacq. increases in a linear fashion with increase in leaf N content (Bolton and Brown 1980). However, McBee and Menn (1969) could not find any correlation between N and levels of chlorophyll a and b in the tissue of six bermudagrasses. The higher apparent photosynthetic rates associated with higher N which also tend to increase leaf thickness and air space in mesophyll may have been due partially to increase light absorption by the thicker leaves but was said to be probably due mostly to soluable protein especially carboxylase protein per unit leaf area in thicker leaves (Bolton and Brown 1980).

The status of N holds the key to the utilization of carbohydrates for growth processes. Adams et al (1974) found that at higher N there was a more rapid turnover of carbohydrates for growth and therefore less total non-structural carbohydrates (TNC) stored when compared with low N where shortage of N prohibited carbohydrate utilization for top growth. Stored TNC was quickly utilized for regrowth provided there was sufficient N. Watschke and Waddington (1974) similarly reported that TNC of 'Merion' bluegrass was lower when fertilized with N and changes in carbohydrates, with time, were influenced by N treatments. N fertilization enchanced turf color, photosynthesis, and dark respiration in bentgrass while stem carbohydrates were reduced (Synder and Schmidt 1974). Walker and Ward (1974) found that net photosynthesis and dark respiration increased as N fertilization increased. Madison (1972) reported that the critical range for tissue nitrate in bluegrass was 500 to 600 ppm, in bentgrass 600 to 1000 ppm, and bermudagrass 800 to 1000 ppm. The relationship between dry tissue production in response to increased levels of N is quadratic (Christians et al 1978). At higher N, top growth is stimulated at the expense of root and rhizome production; turnover of carbohydrates was rapid as plants were using more carbohydrates than were replaced by photosynthesis activity and consequently, less carbohydrate stored (Juska et al 1955 and Adams et al 1974). As N fertilization is increased, a point is reached where carbohydrate for protein synthesis becomes limiting. Thus excess N could lead to gradual carbohydrate starvation until the plants were unable to support themselves (Harrison 1931). Results obtained by Christian et al (1979) showed that maximum tissue production for 'Merion' bluegrass was at

125 ppm N and 144 ppm K and 'Penncross' creeping bent-grass at 96 ppm N and 196 ppm K.

The inverse relationship between N supply and root development is a well known phenomenon. Excessive N, while producing lush quick growing turf, results in poor underground development. Root depth also decreases. Adams et al (1974) hypothesized that at low N supply, roots were relatively less deficient than tops to which little was translocated. However, in the absence of turfgrass population stress, increasing N produced greater root development in time (Roberts and Bredakis 1960). Byrant and Hammes (1973) found that with high N, roots and rhizomes were located more at the 0 to 25 cm layer than deeper in the soil. N increased root diameter and decreased number and rate of root growth. The increase in root length in cases of N deficiency was mainly due to an increase in cell length, whereas, the growth inhibition at high N was brought about by the combined action of reduced cell multiplication and cell elongation. Bosemark (1954) suggested that with increased supply of N, the amount of natural auxin in roots increased correspondingly. Oswalt et al (1959) found N increased the rate of root decomposition after defoliation.

Wear tolerance is an important turfgrass quality. Shearmann and Beard (1973) reported that wear tolerance increased with N application, but at 7.2 kg N/ac/season wear tolerance was reduced. Likewise, shoot density, mat accumulation, verdure, leaf tensile strength, load bearing capacity and percent moisture increased with N increments. Total wall constituents - lignocellulose, cellulose and lignin contents - increased also.

Severity of disease in turfgrass can also be modified by N levels. Reike et al (1973) observed a significant increase in incidence of Fusarium nivale (Fr.) injury in Kentucky bluegrass in early spring when two or more kilograms of N were applied annually. At high N, the turf was also more susceptible to Ustilago striiformis (West.) Niessl during summer. On the other hand, Tifway bermudagrass and 'Medalist II' ryegrass exhibited more severe dollar spot (Sclerotina homoecarpa fer F.T. Bennett) and none at high N ([1]Sartain and Dudeck, 1981).

N fertilization influences the cold, heat and drought tolerance of turfgrasses. Gilbert and Davis (1967) reported that plants with high N were least resistant

[1]Sartain, J.B., and Dudeck. 1981. Personal communication.

to low temperature but addition of K improved cold tolerance. Hendrix and Gilbert (1976) found that high rates of N reduced winter-hardiness of 'Arizona' common bermudagrass. At high N, each increment of water stress was accompanied by a decrease of yield. This response was due to the increase in N availability causing an increase in succulence resulting in reduced sugars in the cell sap (Paul and Madison 1972).

Environmental effects play a significant role in N nutrition of turfgrass. During spring and summer, available N decreased the soluble carbohydrate in stubble and tops in 'Kentucky 31' tall fescue. Injury to centipedegrass with high N in summer was attributed to low carbohydrates and winter killing. Fall and winter N applications resulted in desirable green color, but soluble carbohydrates remained high (Blaser, Schmidt, and Stewart 1967). Similar results were obtained for bluegrass. Net photosynthesis was stimulated by N application in winter, and photosynthesis was high compared to dark respiration.

Potassium

Potassium (K) is the most active of the essential nutrients for plant growth and developmental processes, even though it is not a constituent of living cells. Much K in plants appear in soluble form and may be leached (Juska and Murray 1974). Its role has not been clearly understood but may be more important than previously realised. Fertilization practices on putting greens in current maintenance are more attuned to playing quality than appearance. Use of N is decreased and of K increased. This is particularly true on bentgrass greens (Hoos 1981). In studies by Christians et al (1979), Penncross creeping bentgrass showed maximum root production at a solution concentration of 6 ppm N and 196 ppm K and minimum root production at 150 ppm N and 64 ppm K. Similarly, Gruber (1981) found a high correlation between soil K content and dry matter yield. When K is available in growing media, it is absorbed in large excessive amounts than is required for growth. This "luxury consumption" is stored. Young actively growing turfgrasses has high K but decreases rapidly when the plant reaches maturity. The function of K has been listed by Beard (1974): 1) carbohydrate synthesis and translocation; 2) amino acids and protein synthesis; 3) catalyzing numerous enzymatic reactions including nitrate reduction; 4) regulating transpiration; 5) controlling uptake rate of certain nutrients; and 6) regulating the respiration rate.

Deficiency in K will cause the respiration rate to increase, thereby causing a drain in the carbohydrate reserves. K deficient turf also has higher transpiration rate. When K was not used, both zoysiagrass (Zoysia matrella) and Tiflawn (Tifton 57) bermudagrass had poor appearance (Sturkie and Rouse 1967). Without K, plants developed typical potash deficiency symptom; brown in color, dwarfed in growth, slow to emerge in spring, and damaged by winter cold. K deficiency symptoms in Tifgreen bermudagrass appeared when K tissue level dropped to 18,000 ppm (Menn et al 1970).

K influences 1) rooting; 2) drought, heat and cold hardiness; 3) disease proneness; and 4) wear tolerance, although visual response in terms of shoot, color, density and growth may or may not be exhibited (Beard 1973).

Plants deficient in K respond well to added K. Leaf fresh weight and leaf K content of K deficient 'Windsor' Kentucky bluegrass increased as K level increased to 363 g $K_2O/93m^2$ (McVey 1968). Similarly growth measurements such as clipping weights, weights of underground parts, tops vigor scores, tiller counts and blade widths were higher with K than without (Monroe, Coorts, and Skogley 1969). Markland and Roberts (1967) reported that increasing K levels increased fresh and dry weight, foliage yield and reduced percent dry weight in Washington creeping bentgrass. Waddington et al (1974) in their experiment with Penncross creeping bentgrass, found that clipping weights were not influenced consistently by K source and rate in general, but significant increases due to K occurred with time. Added K also increased K in clippings but decreased N, Ca, Mg, Mn, and Na. On the other hand, shoot density and relative turgidity were not affected in 'Toronto' creeping bentgrass (Shearmann and Beard 1975). Yields of forage coastal bermudagrass also increased with K application (Robinson 1978). Losses of yield and stand of forage coastal bermudagrass due to inadequate K fertility have been reported many times. This has been attributed to winter kill, disease, and lack of physiological hardening of plants (Keisling et al 1979). On the other hand, high rates of K appeared to reduce vegetative growth and promote carbohydrate accumulation at low N in bentgrass (Monroe, Coorts, Skogley 1969). Improper K nutrition may result in poor translocation and storage of carbohydrates, amino-acids and mineral nutrients from aerial plant parts to roots and rhizomes. Juska (1957) found root growth was stimulated more than shoot growth. High K increases high rhizome production and low K lower K in tissue and vigor in the root system. The positive response of roots to increasing K was qradratic. Markland and Roberts (1967) found that fresh weight of creeping bentgrass was maximum at 50 ppm K but dry weight yield of roots were not altered by varying K levels.

The improved root development, particularly at high N was found to improve winter-hardiness. Some species or cultivars responded more effectively to K than others. Juska and Murray (1974) stated that soil fertility, especially levels of K and N, contributed substantially to the degree of variation encountered in evaluating the winter-hardiness of bermudagrass cultivars. Reduction of winter-hardiness of 'Arizona' common bermudagrass due to high N was less when coupled with K (Hendrix and Gilbert 1976). High K slightly reduced hardiness. Similarly, workers on bluegrass and bentgrass reported adequate K in a balanced nutrient regime increased the tolerance to high and low temperature stress (Gilbert and Davis 1967). However, results of Cook and Duff (1974) did not support a critical role of K in low temperature tolerance of Kentucky 31 tall fescue maintained as turf.

Reactions of turfgrasses to diseases may be influenced by K. Turfgrass management tends to encourage a high proportion of actively growing tissue by providing high N. However, high N and low K can result in the accumulation of non-protein N and unused carbohydrate compounds in plant cells. Goss and Gould (1967) stated that such high concentration of sugars and nitrates were favorable for growth of disease organism, and potassium suppressed *Ophiobolus* patch disease caused by the fungus *Ophiobolus graminis* Sacc. var avenae. Similar results, though not significant, were obtained in nutrient studies with *Fusarium* patch disease. Visual scores for resistance to dollar spot caused by *Sclerotinia homoecarpa* showed a trend towards increase in susceptibility on plots with K.

Wear tolerance of turfgrass is also reported to increase proportionately with increasing K level. Associated with higher K levels are thicker cell walls, increased plant vigor, higher cellulose content, and increased turgor pressure. All these may contribute to improved wear tolerance. Stiffening of leaf blade may also be responsible. Shearmann and Beard (1975) reported K fertilization improved wear tolerance. Concurrently, there was an increase in percent K accumulated, load bearing capacity, and leaf tensile strength.

The balance between N and K fertilization is important. Growth measurements have consistently showed a significant N-K interaction. High N without sufficient K can disrupt metabolism. Such disruption is exhibited by an abnormal accumulation of non-protein N, winter killing, disease, and poor density or quality of turf (Wagner 1967). Christians et al (1979) observed an interaction between N and K on quality response of bentgrass grown in solution culture. As K increased, less N was required to attain maximum quality. Gruber (1981) found a high correlation between grass K content and sward yield with heavy N application. [1]Sartain and Dudeck (1981) similarly found that Tifway bermudagrass and Medalist II perennial ryegrass yield was reduced by the exclusion of K at high rate. The maximum double-acid extractable K was reported to be 33 ppm. Increase in N rates did not significantly influence the K content of either turfgrass. Menn and McBee (1970) suggested that the K concentration of Tifgreen bermudagrass must drop below 1.8% before deficiency symptoms appear. Yield and

[1]Sartain, J.B., and A.E. Dudeck. 1981. Personal communication.

N content of Kentucky bluegrass were reduced at levels of K above 100 ppm when N levels were maintained at 65 ppm (Monroe et al 1969). Best recovery of bermudagrass from winter damage was from high N in combination with high K (Juska and Murray 1974).

Mowing

Mowing results in the reduction of the photosynthising apparatus and available photosynthates in turfgrass. However, the turfgrass plant is able to survive mowing and continue new leaf development because the growing point is at the base of the plant (Beard 1973). Nevertheless, there is a range of cutting heights tolerable by different species or cultivars depending on their growth habit. To a large extent, the use of the turf also dictates the mowing height prescribed. Many studies have been conducted on the relationship of cutting heights to growth responses.

Cutting heights influence the quantity of photosynthate available for growth. Investigations have shown a general relationship between cutting heights and growth - the lower the cutting height the less top growth, and root and rhizome production. Top growth is the cumulative of tillering, population density, verdure and shoot growth. Sullivan (1961) found that Kentucky bluegrass produced higher yields of top growth at high cuts. In the first year of their experiment, Goss and Law (1967) obtained similar response in eight varieties of bluegrass. Severe mowing reduced yields of 'Highland' bentgrass (Madison 1962). While severity of defoliation caused significant decrease in top growth, the response of individual components differ. More tillers were produced at shorter cutting height than at higher cuts with fescue. Beard (1973) stated that close mowing stimulated tillering only if the stem apex was removed. Adams et al (1974) in their studies on cultivars of <u>Lolium perenne</u> L. and <u>Poa pratensis</u> L. found that there was no stimulation of tillering at closer mowing except in cultivar S.23 <u>Lolium perenne</u> L., when the reduction of cutting height at very low N resulted in an increase in number of tillers. Work on 'Highland' and 'Seaside' bentgrass showed lower mowing increased plant population (Madison 1962). Observations have shown that verdure of bluegrass, perennial ryegrass and bentgrass cultivars have all increased with increased cutting heights (Madison and Hagan 1962, Wood and Burke 1960, Adams et al 1964, and Madison 1962).

The response of top growth to cutting heights appeared to be influenced by the N supply. It has been suggested that both N supply and cutting height affected the carbohydrate level available for growth and the latter contributes a key triggering mechanism. Sheffer et al (1974) found that total nonstructural carbohydrates (TNC) differed between mowing managements. Rates of physiological reactions such as photosynthesis and dark respiration were modified by mowing heights - rates were higher with decreased cutting heights (Krans and Beard 1975), and consequently the amount of N required for the utilization of the available carbohydrates depended on the quantity of photosynthates available. At low N, the low cutting height - low top growth relationship does not hold. Adams et al (1974) demonstrated that both species, *Lolium perenne* L. and *Poa pratensis* L., had least growth at the lowest cutting height. Similar results were obtained in a field experiment with perennial ryegrass (Adams 1980). The investigators interpreted the response as being due to less N being necessary for maximum top growth at lower cutting heights because of the reduced available carbohydrate. Cinch et al (1974) found that crude protein in Kentucky bluegrass cultivars was increased at lowered mowing height. On the other hand, at high N, top growth increased with an increase in cutting height in the experiment with *Lolium perenne* L. and *Poa pratensis* L. Similar results were obtained previously by Juska et al (1956) when the greatest yield was obtained with high N and high cut. This was because at higher cut there was a higher requirement for basal N turnover for survival, and hence greater N level necessary for growth. At higher N there was a more rapid turnover of carbohydrate for growth, hence less TNC was stored. The above responses indicate the interaction of the two variables. Juska and Murray (1974) found this interaction to be significant for clippings, crowns, and roots in Kentucky bluegrass.

Numerous experiments have supported the notion that root development responds reciprocally to cutting heights. Early work by Harrison (1931) showed that continuous low cut was detrimental to the production of rhizomes, and tops, as well as to seed production of Kentucky bluegrass. The shorter the grass was cut the more leaf area was reduced and the smaller the quantity of roots produced. Madison (1962) reported that roots of 'Seaside' bentgrass were reduced with shorter mowing. Root yields of bluegrass and ryegrass were increased with increased cutting heights (Adams et al 1974). Heavy N and low cutting inhibit root and rhizome development.

Juska et al (1955) stated that a combination of both low cutting and high N level reduced substantially growth to the greatest extent in their study on the extraction of soil moisture by 'Merion' bluegrass. At low N, top growth of bluegrass and ryegrass was greater at low cuts and quantity of roots was greater at high cuts (Adams et al 1974). These workers thus hypothesised that top growth took precedence over root growth.

Cutting heights have also been reported to influence color and chlorophyll content of turf. In their investigation, Biran et al (1981) found that both C_3 and C_4 grasses had higher chlorophyll content at high cutting height. This was in agreement with the observation made by Madison (1962) on 'Seaside' bentgrass.

Recent investigation has shown that C_3 and C_4 grasses responded differently to cutting heights. At high cut, C_3 grasses showed a permanent increase in water consumption and growth, but in C_4 grasses there was only an initial increase before decreasing to the original level. Cutting height therefore appeared to permanently improve vigor in C_3 cultivars but only temporarily in C_4 species and cultivars. Madison and Hagan (1961) similarly showed an increase in water consumption with cutting height although Burns (1960) found no effect of cutting heights in water consumption.

Starr and Redoo (1981) also demonstrated that clipping management had a large effect upon the distribution of fertilizer N applied to turfgrass.

CHAPTER III

MATERIALS AND METHODS

Experiment I: Mowing and N Fertilization Studies on Six Warm Season Turfgrasses.

This experiment was conducted at the Waimanalo Research Station, University of Hawaii, during the period September 9 to December 8, 1981. The average daily temperature and relative humidity were 28.4 C ranging from 25.5 to 30.5 C, and 71.1% ranging from 61 - 77% respectively. The rainfall records are shown in Table 1.

An existing 'Sunturf' bermudagrass (*Cynodon magennesii* Hurcombe) on the experimental area was killed by using glyphosate. Two applications were made at an interval of eighteen days at the rate of 3.4 kg/ha. About a month later, the entire area was ploughed and levelled before the turfgrassess were planted.

A factorial treatment set consisting of six turf

Table 1

RAINFALL (SEPTEMBER 9 TO DECEMBER 7, 1981) AT THE WAIMANALO RESEARCH STATION

	September	October	November	December
1	-	0	2.47	0.02
2	-	0	0.35	0.05
3	-	0.01	0.22	0.02
4	-	0	0.01	0
5	-	0	0.12	0.03
6	-	0	0.06	0.07
7	-	0.02	0.07	0.24
8	-	0.01	0	-
9	0.01	0.02	0	-
10	0.01	0.08	0.03	-
11	0	0	0.01	-
12	0.08	0.02	0	-
13	0.31	0.01	0.01	-
14	0.02	0.35	0.01	-
15	0	0	0.10	-
16	0.01	0.01	0.29	-
17	0	0	1.26	-
18	0	0.05	0.01	-
19	0.22	0.01	0.01	-
20	0.30	0	0.01	-
21	0.11	0.01	0	-
22	0	0	0.01	-
23	0.09	0	0.09	-
24	0.01	0.01	0.28	-
25	0	0	0.03	-
26	0.01	0.04	0.05	-
27	0	0.15	0.18	-
28	0.01	0.45	0	-
29	0.01	0.52	0	-
30	0	0.02	0.12	-
31	-	0.75	-	-

species, two mowing heights, and three fertilization levels were used as follow:

I. Turf species

1. Bermudagrass (*Cynodon dactylon* (L.) Pers.)
2. Carpetgrass (*Axonopus affinis* Chase)
3. Centipedegrass (*Eremochloa ophiuroides* (Munro.) Hack.)
4. Seashore paspalum (*Paspalum vaginatum* Swartz)
5. St. Augustinegrass (*Stenotaphrum secundatum* (Walt.) Kuntze)
6. Zoysiagrass (*Zoysia japonica* Steud.)

II. Mowing heights (Table 2)

1. recommended low for the particular turf species
2. recommended high for the particular turf species

III. N fertilization levels (Table 3)

1. low recommended for the particular turf species
2. medium recommended for the particular turf species
3. high recommended for the particular turf species

Bermudagrass, carpetgrass, centipedegrass and St. Augustinegrass plots were replicated three times whereas seashore paspalum and zoysiagrass were unreplicated because there were insufficient propagating material. Therefore, data for these were not statistically analysed. The size of each main turf plot in a replication was 5.25 m X 4.4 m, the subplot for each mowing height was 5.25 m X 2.2 m and the sub-subplot for each N fertilization level was 1.75 m X 2.2 m. Main plots were arranged in a randomized complete block design. An alleyway of about 0.5 m separated the individual main plots.

Bermudagrass, carpetgrass, centipedegrass,and zoysiagrass were established by means of seeds and seashore paspalum and St. Augustinegrass by stolons. Seeds and stolons were sown and planted in late February 1981, irrigated three times a day on alternate days. During the establishment phase, urea was applied monthly at the rate of 0.45 kg N/93m^2/month to all the plots. Mowing was carried out weekly at the high recommended mowing heights for individual turfgrasses, using a rotary mower. All clippings were removed. The turf plots were also weeded as needed until they were fully established and treatments initiated. Pesticides were applied as required throughout the experiment.

After six and a half months, treatments listed in Tables 2 and 3 were applied. Three levels of N were used. In view of the small quantity of N being applied on some of the turfgrasses, ammonium sulphate was chosen as the nitrogen source because of its lower N concentration than urea, therefore, more uniform distribution. The fertilizer was applied monthly using a 0.47 L hand shaker. Subplots were mowed weekly to the respective recommended low and high mowing heights (Table 2). The treatments were continued for three months. Experimental data were taken beginning six weeks after the commencement of the treatments.

Visual ratings served as a means of evaluating turfgrass quality in response to the treatment given. As aesthetics, and not yield, is the crux of turfgrass management, this parameter has been widely used by many turfgrass researchers to measure turfgrass quality. Amongst them were Fujimoto (1979) when determining the optimum nutrient concentration for Tifway bermudagrass (Cynodon dactylon X C. transvaalensis L. Burtt-Davey), Juska and Murray (1974) in their assessment of the performance of bermudagrass in the transition zone as affected by potassium and nitrogen, Mantell and Stanhill (1966) in their studies on the response of kikuyugrass

(*Pennisetum clandestinum* Hochst) to irrigation and nitrogen treatment, Menn and McBee (1970) in determining the nutritional requirement for Tifgreen bermudagrass (*Cynodon dactylon* X *C. transvaalensis* L. Burtt-Davey), Monroe, Coorts and Skogley (1969) in evaluating the effects of N-P levels on growth and chemical composition of Kentucky bluegrass (*Poa pratensis* L.), and Synder and Schmidt (1974) in their study on N and Fe fertilization of bentgrass (*Agrostis palustris* Huds.). The ratings were based on color and general appearance on a 1 to 5 scale: 1 being the poorest, 3 is "acceptable", and 5 the "best" turf quality. When the turf exhibited good quality it was accorded with scores of 4 and above.

Dry weights of clippings were recorded biweekly. The two longitudinal borders of each subplot were mowed first before collecting the clippings for dry weight determination. A rotary mower was used to cut a strip of 0.5 m X 1.1 m at the center of each sub-subplot and the clippings were collected in the catcher. Clippings were then transferred to individual brown paper bags and dried in a forced-draft oven at 60 C for 24 hours after which they were weighed.

Chlorophyll content was determined monthly. The method used was that described by Johnson (1974). The dried clippings were ground in a Wiley mill to pass a 40-mesh screen. These were also used for tissue analysis. To extract the chlorophyll, 20 mg of each sample of ground clippings was immersed in 20 ml methanol for 22 - 24 hours. Optical density (OD) of each sample was read from a Unicam SP 1800 Ultraviolet Spectrophotometer at 650 nm and 665 nm. Relative chlorophyll content data was then calculated, using Johnson's formula (25.6 X OD_{650} + 4.0 X OD_{665})/CW subsample).

Root growth was also observed *in situ* in mini-rhizotrons, similar to those described by Bohm (1974). A motorised borer with 5 cm diameter blade was used to drill a 60 cm deep hole in the center of each sub-subplot and the sides of the hole were lightly brushed to loosen the compact surfaces resulting from the drilling process. A glass tube 0.61 m long (external diameter 45 mm, thickness of wall 2 mm) was then inserted vertically into the hole with the upper edge flushed to the soil surface. The space between the tube and the soil was filled with soil from the plots which has been passed through a 9-mesh sieve. The top of the tube was sealed with a No 9 black rubber stopper. A small 1.5 V bulb connected to two external batteries was lowered into the rhizotron whenever root lengths were being measured. Six readings including the longest root seen in the rhizotron were measured for each sub-subplot these were averaged to obtain the root depth data.

Ground turfgrass clippings were analyzed monthly by means of X-ray quantometer by the Soil and Tissue Testing Service Center, College of Agriculture and Human Resources, University of Hawaii.

Table 2

MOWING HEIGHT TREATMENTS USED IN EXPERIMENT I, WAIMANALO RESEARCH STATION

Turf species	Mowing heights (cm)	
	Low	High
Bermudagrass	1.25	2.50
Carpetgrass	2.50	5.00
Centipedegreaa	2.50	5.00
Seashore paspalum	1.25	2.50
St. Augustinegrass	3.75	7.50
Zoysiagrass	2.50	5.00

Table 3

N TREATMENTS USED IN EXPERIMENT I,
WAIMANALO RESEARCH STATION

Turf species	N levels ($kg/93m^2/month$)		
	Low	Medium	High
Bermudagrass	0.45	0.56	0.67
Carpetgrass	0.11	0.17	0.23
Centipedegrass	0.11	0.17	0.23
Seashore paspalum	0.08	0.19	0.30
St. Augustinegrass	0.33	0.39	0.45
Zoysiagrass	0.33	0.39	0.45

Experiment II: Response of Carpetgrass (*Axonopus affinis* Chase) to N-K fertilization

Carpetgrass was selected for studies of its responses to N-K fertilization because of its importance as a turfgrass in the humid tropics. Relatively few works have been reported on this. Although commonly grown because of its ease of establishment, it has relatively poor turf characteristics such as poor drought and wear tolerances (Martin 1975, Beard 1973). Nitrogen (N) and potassium (K) nutrition are known to play important roles in influencing turf quality in respect of root development, disease resistance and reaction, heat and cold and drought hardiness, and wear tolerances (Christians et al 1979, Monroe et al 1969, Juska 1966, Beard 1973, and Walker and Ward 1974).

Pot cultures were grown in the Pope Laboratory Glasshouse facility at the University of Hawaii, Manoa Campus, Honolulu, Hawaii. The maximum temperature in the glasshouse ranged from 31.1 to 43.3 C and the minimum temperature from 18.3 to 24.4 C.

Black polyethylene pots, 15 cm in diameter and 17.5

cm deep were filled with washed pure silica sand. Seeds were sown at the rate of 1.13 kg/93m^2 and the pots were kept under mist irrigation for about a month. After removing from the mist bench, each pot was given 250 ml of 50% Hoagland Solution II (Hoagland and Arnon 1951) for six weeks on alternate days during the week. On the other days only deionised water was used and the pots were leached on the seventh day with 1 L of deionised water to prevent salt accumulation. In order to allow the plants to utilize as much of the nutrients applied as possible, 250 ml of a 25% Hoagland Solution was applied daily for a month before starting the treatments. No additional watering was given. Leaching was similarly carried out weekly. The turf height was maintained at 5 cm height by clipping weekly.

The turf was fully established and uniform when treatment were applied. A modified 25% Hoagland Solution, lacking in N and K with 5 ppm Fe and usual micronutrients was used as the basic solution. Varying levels of N and K in combination were added: the levels of N were 6.25, 12.5, 25 and 50 ppm and K levels were 7.5, 15, 30 and 60 ppm. The source of N was NH_4NO_3 and K was KCl. There were four replications of the resulting treatments (4X4 factorial) arranged in a randomized complete block design. Treatment solutions were prepared and applied daily for six days each week. The pH was adjusted to 6.0 $\pm$ 0.2 with 1% NaOH solution. Each pot was given 250 ml. The pots were leached once a week using 1 L deionised water for each pot and allowed to drain for 24 hours before applying further treatments. The treatments were followed for about two months (September 16 to November 12, 1981). Experimental data were collected weekly.

Five main parameters were used to evaluate the responses of the carpetgrass to the treatment:

1. Visual ratings of turfgrass quality of individual pots were carried out weekly at about 7.15 a.m. so that the glare was less intense and the reflectance on the turfgrass reduced in the estimation of its color quality. As in Experiment I, the rating was based mainly on general appearance and color. The scale used range from 1 to 5 with 1 having the poorest and 5 the "best" turf. A score of 3 indicated an "acceptable" turf quality. To avoid personal bias, the treatments for the individual pots were not made known to the rater.

2. Growth response of the turf was measured by determining clipping dry weights. The turf in each pot was clipped to a height of 5 cm weekly, using a teflon coated floating blade grass shears. All the clippings from each pot were collected in a tray first before transferring into individual brown paper bags. These were dried in a forced-draft over at 60 C for 24 hours and individual dried weights were determined.

3. Chlorophyll was extracted and chlorophyll content determined as described in Experiment I. Readings were taken weekly for eight consecutive weeks.

4. Root dry weights were measured at the end of the experiment. The tops of each pot were removed, leaving only the roots. These were then carefully washed free of sand and placed in individual brown paper bags and dried in a forced-draft oven at 60 C for 24 hours, then weighed.

5. Shoot dry weights were also obtained at the end of the experiment.

As in Experiment I, tissue analysis for N, P, and K content was conducted by means of X-ray quantometer. Clippings were ground in a Wiley mill and passed a 40-mesh screen before sending them to the laboratory. The amount of ground clippings from some samples was very small. Consequently, clippings of the four replicates were pooled and combined for each treatment being analyzed. Only biweekly samples were sent for analysis.

Analysis of Data

As the recommended low and high mowing heights and recommended low, medium, and high N treatments (Tables 2 and 3) varies from species to species in Experiment I, comparison between species was not carried out. Effects of mowing heights and N treatments on those species with replications (bermudagrass, carpetgrass, centipedegrass, and St. Augustinegrass) manifested through visual ratings, clipping dry weights, root depths, and %N tissue content were analyzed using analysis of variance (ANOVA) for randomized complete block design as shown in Table 4. The parameter means were compared using Bayesian Least Significant Difference (BLSD) at 5% level.

Similarly, data of the glasshouse experiment were analyzed using randomized block design for a 4 x 4 factorial (N x K) on a weekly basis (Table 5). An overall ANOVA was also performed (Table 6).

Statistical analysis were computed with the aid of the HP - 2000 computer at the University of Hawaii Computer Center, Honolulu, Hawaii using SAS integrated system.

Table 4

SOURCES OF VARIATION AND DEGREES OF FREEDOM FOR WEEKLY ANALYSIS OF THE VARIOUS PARAMETERS IN THE FIELD EXPERIMENT

Sources of variation	df
Total	17
MH	1
N	2
MH X N	2
Replications	2
Error	10

Table 5

SOURCES OF VARIATION AND DEGREES OF FREEDOM FOR THE GLASSHOUSE EXPERIMENT.
WEEKLY ANALYSIS

Sources of variation	df
Total	63
N	3
K	3
N X K	9
Replications	3
Error	45

Table 6

SOURCES OF VARIATION AND DEGREES OF FREEDOM FOR THE GLASSHOUSE EXPERIMENT. AVERAGE OF ALL DATES.

Sources of variation	df
Total	115
N	3
K	3
N X K	9
Replications	3
Error	493

CHAPTER IV

RESULTS

Experiment I: Mowing height and N fertilization studies on six warm season turfgrasses.

A. Main effects of mowing height

The effects of mowing height on growth parameters of the six turf species were measured for a period of six weeks after treatments were applied (six weeks before the first data was collected). Visual ratings and clipping dry weights were recorded on a weekly basis and chlorophyll analysis and root depths once a month. Generally, the effects of mowing height increased with time, with larger differences at the end of the experiment than at the beginning. For this reason, only the data for the final week (twelfth week after treatments were initiated) are given in Table 7. However, clipping dry weights of carpetgrass were changed for weeks six, eight, and ten, and these are given separately in Table 8.

1. Visual Ratings

Visual ratings for bermudagrass and centipedegrass were higher at the low mowing heights. Carpetgrass and St. Augustinegrass had higher visual ratings at the high mowing heights. Zoysiagrass and seashore paspalum were single replicates, however, there appeared to be no effect of mowing height on visual ratings of these two species.

2. Clipping Dry Weights

Clipping dry weights were greater at the low mowing height for St. Augustinegrass and carpetgrass (at weeks six, eight, and ten). However, that of bermudagrass was greater at the high mowing height, and that of centipedegrass was unaffected by mowing height. Clipping dry weight of zoysiagrass did not appear to be affected by mowing heights, while seashore paspalum appeared to react similarly to St. Augustinegrass.

3. Chlorophyll Contents

Chlorophyll content of bermudagrass was higher at the low mowing height, that of carpetgrass and centipedegrass were unaffected by mowing heights, and St. Augustinegrass had higher chlorophyll contents at high mowing treatment. From the single replicate of zoysiagrass and seashore paspalum, it appears that the effect of mowing heights on chlorophyll contents was negligible.

4. Root Depths

Low mowing height resulted in a significant decrease in rooting depth in St. Augustinegrass. While reductions in root depth from low mowing for the other species were not significant (P = 0.05), there was a trend toward shorter roots with low mowing in all except centipedegrass.

Mowing heights had small effects on %N contents in carpetgrass and centipedegrass only. Higher contents were associated with low mowing height.

B. Main effects of N Fertilization

As in mowing height measurement, evaluation of N fertilization effects on the growth parameters of the six turf species commenced on the sixth week after the initiation of treatments. Visual ratings and clipping dry weights were recorded on a biweekly basis, and root depths and chlorophyll contents were read monthly. Nitrogen contents in leaf tissues were similarly analysed once a month. Data for the final week are presented in Table 9.

1. Visual Ratings

No difference in visual ratings were noted between the different levels of N treatments for all species.

2. Clipping Dry Weights

Bermudagrass produced more clipping dry weight at low than medium levels of N. There was no difference between medium and high levels. Clipping dry weight effects between the medium and high levels in carpetgrass were observed only in the first measurement (week six). No difference was noted after this for this species. Clipping dry weight of centipedegrass increased with increasing N levels. St. Augustinegrass, on the other hand, did not respond to differences in N treatments within the range examined. Higher N treatments appeared to result in higher clipping dry weight of zoysiagrass and seashore paspalum

3. Chlorophyll Contents

Effects of N fertilization on chlorophyll contents were not significant for all species with replications except centipedegrass where higher chlorophyll contents values were associated with higher N fertilization. Chlorophyll content of zoysiagrass appeared not to be affected by N treatments whereas seashore paspalum seemed to have increasing chlorophyll content with higher N.

4. Root Depths

Only centipedegrass showed significant response to N treatments. Relationship was inverse, i.e., increasing N levels decreased root depths. Difference was mainly between the high level and other levels, although difference in root depths for other species were not significant ($P = 0.05$), this trend was present. Zoysiagrass appeared to show similar response whereas seashore paspalum seemed to react variably to increasing N treatments.

5. Percent N

Increasing N fertilization levels resulted in increasing N content in carpetgrass and centipedegrass. In carpetgrass, the difference was between the low and high recommended levels whereas in centipedegrass, %N increased with increasing N levels. N contents of bermudagrass and St. Augustinegrass were not affected by increasing N application. Likewise, N content in zoysiagrass seemed not to be affected, but seashore paspalum exhibited a trend toward increased N content with increased N fertilization in its single replication.

C. Mowing Heights and N Fertilization Interaction

With the exception of clipping dry weights in bermudagrass, no interaction effects were shown in all the parameters and leaf tissue N contents. The data are shown in Table 10. The highest clipping dry weight value was obtained from the combination between low mowing height and low fertilization level. Medium range clipping dry weight values were obtained at higher mowing height regardless of N level. When low mowing was combined with medium N level, the least clipping dry weight was collected.

Table 7

EFFECTS OF MOWING HEIGHT ON VARIOUS GROWTH PARAMETERS OF TURFGRASS SPECIES. AVERAGE OF THREE REPLICATIONS[u] AND THREE N FERTILIZATION LEVELS.

Turfgrass	MH[v]	VR[w]	CW[x]	CC[y]	RD[z]	%N
Bermudagrass	L	5.00*	16.66	5.41*	10.52	4.29
	H	4.50	19.25*	4.95	12.50	4.23
Carpetgrass	L	3.50	5.61	4.22	9.65	3.08*
	H	4.12*	12.41	4.44	10.97	2.92
Centipedegrass	L	4.50*	8.07	4.43	10.11	2.89*
	H	4.00	7.79	4.37	10.05	2.72
St. Augustine-	L	4.00	6.06*	3.77	14.19	2.97
grass	H	4.43*	4.10	4.25*	17.16*	2.98
Zoysiagrass	L	3.00	4.11	2.90	9.84	2.47
	H	3.00	3.99	3.04	11.62	2.68
Seashore	L	4.00	3.16	3.62	10.28	2.95
paspalum	H	3.75	1.91	3.72	12.36	2.92

* Means are significantly different (P = 0.05) when compared between mowing heights for each species separately.

u - Zoysiagrass and seashore paspalum were unreplicated, all other species were replicated three times.

v - Mowing heights were low and high recommended for that particular species. (See Materials and Methods for exact heights.)

w - VR = Visual Ratings on scale of 1 - 5 with 1 poorest and 5 best.

x - CW = Clipping Dry Weights ($g/0.55m^2$)

y - CC = Chlorophyll Contents (mg/g dry wt)

z - RD = Root Depths (cm)

Table 8

EFFECTS OF MOWING HEIGHT ON CLIPPING DRY WEIGHTS OF CARPETGRASS AT WEEKS SIX, EIGHT, AND TEN AFTER INITIATING MOWING TREATMENTS.

Mowing Height	Clipping Dry Weights (g/0.55m^2)		
	Week 6	Week 8	Week 10
L	2.14*	7.16*	8.98*
H	1.14	3.41	4.75

* Means in the same column are significantly different (P = 0.05).

Table 9

EFFECTS OF N FERTILIZATION LEVELS ON VARIOUS GROWTH PARAMETERS OF SIX TURFGRASS SPECIES. AVERAGE OF THREE REPLICATIONS[u] AND TWO MOWING HEIGHTS.

Turfgrass	N level[v]	VR[w]	CW[x]	CC[y]	RD[z]	%N
Bermudagrass	L	4.75	22.23a*	5.18	12.58	4.44
	M	4.75	15.21b	5.08	11.01	4.41
	H	4.75	16.42b	5.27	10.38	3.94
Carpetgrass	L	3.85	4.06	4.24	11.23	2.88a*
	M	3.80	17.42	4.49	9.52	3.03b
	H	3.85	5.15	4.26	10.52	3.09b
Centipedegrass	L	4.25	7.23a*	4.00a*	11.61a*	2.66a*
	M	4.25	7.78ab	4.46b	10.24a	2.81b
	H	4.25	8.78b	4.75c	8.39b	2.95c
St. Augustine-grass	L	4.22	5.08	3.91	17.02a*	2.99
	M	4.22	5.14	4.12	14.19ab	2.96
	H	4.22	5.03	4.00	15.81b	2.97
Zoysaigrass	L	3.00	3.62	2.53	11.56	2.51
	M	3.00	4.09	3.26	10.31	2.60
	H	3.00	4.43	3.14	9.59	2.62
Seashore paspalum	L	3.88	4.74	3.30	12.21	2.81
	M	3.88	4.80	3.79	10.71	2.99
	H	3.88	7.21	3.92	11.05	3.01

u - Bermudagrass, carpetgrass, centipedegrass, and St. Augustinegrass were replicated three times; Zoysiagrass and seashore paspalum were single replicates.

v - N levels were low, medium, and high recommended for each species. (For exact levels, See Materials and Methods Section.)

w - VR = Visual Ratings on scale of 1 - 5 with 1 poorest and 5 best.

x - CW = Clipping Dry Weights ($g/0.55m^2$)

y - CC = Chlorophyll Contents (mg/g dry wt)

z - RD = Root Depths (cm)

Table 10

INFLUENCE OF MOWING HEIGHT AND N FERTILIZATION LEVELS ON VARIOUS GROWTH PARAMETERS OF SIX TURF SPECIES[t]. AVERAGE OF THREE REPLICATIONS.

Mowing Height[u]	N Fertilization level[v]	VR[w]	CW[x]	CC[y]	RD[z]	%N
Bermudagrass						
L	L	5.00	24.42a*	5.24	10.71	4.57
L	M	5.00	12.29c	5.54	9.69	4.79
L	H	5.00	13.28c	5.44	11.76	3.51
H	L	4.00	20.05b	5.11	14.45	4.29
H	M	4.00	18.13b	4.60	12.32	4.02
H	H	4.50	19.56b	5.11	9.60	4.36
Carpetgrass						
L	L	3.50	6.02	4.19	9.30	3.03
L	M	3.50	4.78	4.48	9.67	3.09
L	H	3.50	6.03	3.99	9.98	3.13
H	L	4.20	2.11	4.28	13.17	2.73
H	M	4.10	3.05	4.51	9.37	2.97
H	H	4.20	4.27	4.52	10.39	3.05
Centipedegrass						
L	L	4.50	8.03	3.99	11.75	2.74
L	M	4.50	7.83	4.42	11.35	2.89
L	H	4.50	8.34	8.23	8.23	3.04
H	L	4.00	6.42	11.47	11.47	2.57
H	M	4.00	7.72	10.12	10.12	2.72
H	H	4.00	9.22	8.56	8.56	2.85
St. Augustinegrass						
L	L	4.00	6.45	3.55	15.16	2.94
L	M	4.00	5.91	4.02	12.55	2.98
L	H	4.00	5.82	3.73	14.85	2.99
H	L	4.43	3.71	4.26	18.89	3.03
H	M	4.43	4.37	4.21	15.84	2.94
H	H	4.43	4.23	4.27	16.77	2.96

Table 10 (Continued)

INFLUENCE OF MOWING HEIGHT AND N FERTILIZATION LEVELS ON VARIOUS GROWTH PARAMETERS OF SIX TURF SPECIES[t]. AVERAGE OF THREE REPLICATIONS.

Mowing Height[u]	N Fertilization level[v]	VR[w]	CW[x]	CC[y]	RD[z]	%N
Zoysiagrass						
L	L	3.00	3.79	3.35	10.18	2.52
L	M	3.00	4.79	3.35	8.77	2.58
L	H	3.00	3.74	3.23	10.58	2.32
H	L	3.00	5.07	2.65	9.00	2.72
H	M	3.00	3.39	3.08	11.85	2.62
H	H	3.00	3.50	2.40	12.55	2.69
Seashore Paspalum						
L	L	4.00	3.57	3.11	11.48	2.92
L	M	4.00	3.07	2.73	9.17	3.00
L	H	4.00	2.84	2.82	10.20	2.93
H	L	3.75	1.67	1.96	12.93	2.69
H	M	3.75	2.70	2.48	12.25	2.98
H	H	3.75	1.36	1.89	11.90	3.08

* Means are significantly different (BLSD - 0.05) when compared between treatments for each species separately. Means followed by the same letter do not differ significantly.

t - Zoysiagrass and seashore paspalum were unreplicated, all other species were replicated three times.

u - Mowing heights were low, and high recommended for particular species. (See Materials and Methods for exact heights.)

v - N levels were low, medium, and high recommended for each species. (For exact levels, See Materials and Methods Section.)

w - VR = Visual Ratings on scale of 1 - 5 with 1 poorest and 5 best.

x - CW = Clipping Dry Weights ($g/0.55m^2$)

y - CC = Chlorophyll Contents (mg/g dry wt)

z - RD = Root Depths (cm)

Comparison of Parameters (Experiment I)

Correlations between the growth parameters used including %N were computed for the four species which were replicated. The correlation matrices of these turfgrasses for the final week's data are in Tables 11 to 14. Significance was determined at the probability value 0.05.

1. Visual ratings and clipping dry weights

In St. Augustinegrass, visual ratings were negatively correlated with clipping dry weights. The other species did not show any correlation between these two parameters.

2. Visual ratings and chlorophyll contents

Visual ratings were positively correlated to chlorophyll contents in both bermudagrass and St. Augustinegrass where mowing heights were highly correlated with these two parameters. There was no correlation between these two parameters for carpetgrass and centipedegrass.

3. Visual ratings and root depths

There was no correlation between visual ratings and root depth.

4. Visual ratings and %N

Visual ratings were negatively correlated with tissue N content in carpetgrass. No relationship was observed in the other species.

5. Clipping dry weights and chlorophyll contents

In evaluating the growth responses in centipedegrass, there was a negative correlation between clipping dry weights and chlorophyll contents. No correlations were seen in the other species.

6. Clipping dry weights and root depths

A negative correlation between clipping dry weights and root depths was seen in centipedegrass but in bermudagrass, the relationship was positive. There was no correlation between these two parameters in carpetgrass and St. Augustinegrass.

7. Clipping dry weights and %N

Centipedegrass which responded to N treatment in respect of clipping dry weights, demonstrated a positive correlation between clipping dry weights and leaf tissue N content.

8. Chlorophyll contents and root depths

Chlorophyll contents were negatively correlated to root depths in centipedegrass. No correlation between these two parameters were seen in the other species.

9. Chlorophyll contents and %N

Positive correlation between chlorophyll contents and %N was seen only in centipedegrass.

10. Root depths and %N

As expected, a negative correlation existed between root depths and %N in centipedegrass. No correlation were seen in the other species.

Table 11

CORRELATION MATRIX OF FIVE PARAMETERS ON BERMUDAGRASS - WEEK 12 (EXPERIMENT I)

	VR[w]	CW[x]	CC[y]	RD[z]	%N
VR	1.000	-0.249	0.540*	-0.217	0.038
CW	-0.249	1.000	-0.263	0.519*	0.108
CC	0.540*	-0.263	1.000	-0.158	0.139
RD	0.217	0.519*	-0.158	1.000	-0.364
%N	0.038	0.108	0.138	-0.364	1.000

* Significant correlation at P = 0.05

No of observations = 18

w - VR = Visual Ratings on scale of 1 - 5 with 1 poorest and 5 best

x - CW = Clipping Dry Weight ($g/0.55m^2$)

y - CC = Chlorophyll Content (mg/g dry wt)

z - RD = Root Depth (cm)

Table 12

CORRELATION MATRIX OF FIVE PARAMETERS ON CARPETGRASS - WEEK 12 (EXPERIMENT I)

	VR[w]	CW[x]	CC[y]	RD[z]	%N
VR	1.000	0.266	0.327	0.385	-0.526*
CW	0.266	1.000	0.121	-0.111	-0.085
CC	0.327	0.121	1.000	-0.039	0.170
RD	0.385	-0.111	-0.039	1.000	-0.311
%N	-0.526*	-0.085	0.170	-0.311	1.000

* Significant correlation at P = 0.05

No of observations = 18

w - VR = Visual Ratings on scale of 1 - 5 with 1 poorest and 5 best

x - CW = Clipping Dry Weight (g/0.55m^2)

y - CC = Chlorophyll Content (mg/g dry wt)

z - RD = Root Depth (cm)

Table 13

CORRELATION MATRIX OF FIVE PARAMETERS ON CENTIPEDEGRASS - WEEK 12 (EXPERIMENT I)

	VR^w	CW^x	CC^y	RD^z	%N
VR	1.000	0.114	0.074	0.017	0.397
CW	0.114	1.000	0.303	-0.714*	0.506*
CC	0.074	0.303	1.000	-0.547*	0.467*
RD	0.017	-0.714	-0.547*	1.000	-0.703*
%N	0.397	0.506*	0.467*	-0.703*	1.000

* Significant correlation at P = 0.05

No of observations = 18

w - VR = Visual Ratings on scale of 1 - 5 with 1 poorest and 5 best

x - CW = Clipping Dry Weight ($g/0.55m^2$)

y - CC = Chlorophyll Content (mg/g dry wt)

z - RD = Root Depth (cm)

Table 14

CORRELATION MATRIX OF FIVE PARAMETERS ON ST. AUGUSTINEGRASS - WEEK 12 (EXPERIMENT I)

	VR^w	CW^x	CC^y	RD^z	%N
VR	1.000	-0.653*	0.568*	0.156	0.147
CW	-0.653*	1.000	-0.442	-0.235	0.231
CC	0.568*	-0.442	1.000	0.169	0.210
RD	0.156	-0.235	0.169	1.000	-0.376
%N	0.147	0.231	0.210	-0.376	1.000

* Significant correlation at P = 0.05

No of observations = 18

w - VR = Visual Ratings on scale of 1 - 5 with 1 poorest and 5 best

x - CW = Clipping Dry Weight ($g/0.55m^2$)

y - CC = Chlorophyll Content (mg/g dry wt)

z - RD = Root Depth (cm)

Experiment II: Response of Carpetgrass to N-K Fertilization.

A. N treatments

Increasing N fertilization had greatly increased visual ratings, clipping dry weights, and chlorophyll contents. The overall mean N treatment effects are shown in Table 15. Within the concentration range (6.25 ppm to 50 ppm) studied, visual ratings increased nearly linearly with increasing nitrogen concentration. The differences between different N levels were all highly significant. This trend was generally observed for all eight weeks although the actual values showed fluctuations between weeks. Tissue analysis similarly showed a positive relationship in the contents of N, P, K, magnesium (Mg), and sulphur (S) but a decreasing trend for silica (Si). Root dry weights also decreased with N fertilization above 12.5 ppm.

1. Visual Ratings

Response of carpetgrass to N treatments was manifested in visual ratings after the second week of application at 6.25, 12.5, and 25 ppm N. The reduction in visual quality became obvious especially after the fifth week for those pots with low N ($\leq$12.5 ppm). At this stage although visual rating was considered "acceptable", the turf color tended to have a more yellowish hue, leaves were thinner and narrower, and growth reduced and slower. Turf with visual ratings below 4 exhibited these characteristics. On the other hand, N levels of 25 and 50 ppm continued to produce good visual quality turf with visual ratings of 4 and above. These were green, fast growing, and generally dense. While 50 ppm gave the highest visual rating value of 5, the turf tend to be very luxuriant and the leaves were very broad but thinner. Overall visual rating data and N levels were significantly correlated ($r = 0.69$, $P = 0.01$).

2. Clipping Dry Weights

Yields of clipping dry weights increased with N levels. Response to treatments was again noticed at the second week for the two lower N levels. Clipping dry weight yields continued to decrease until the fifth and sixth week after which it increased slightly at the seventh week and then decreased again. Turf receiving 25 ppm N did not vary much in yield until after the third week and then assumed similar growth response at the lower N levels. At 50 ppm N, there was an increase in clipping dry weight yield up to the third week before responding in similar manner as the other N levels. The differences in clipping dry weight in response to the different N levels were all significantly different ($P = 0.01$). Clipping dry weights were also significantly correlated to N levels ($r = 0.638$, $P = 0.01$).

3. Chlorophyll Contents

The correlation between chlorophyll contents and N levels were highly significant ($r = 0.917$, $P = 0.01$). Chlorophyll content increased as N levels increased from 6.25 to 50 ppm. The differences in response were all highly significant ($P = 0.01$), irrespective of weeks. At the two higher N levels (25 and 50 ppm), chlorophyll contents increased with time until the seventh week where they showed a decrease. On the other hand, the lower N levels (6.25 ppm and 12.5 ppm) showed a decline in chlorophyll contents initially and then started to decrease again after the seventh week.

4. Shoot Dry Weights and Root Dry Weights

Shoot dry weights and root dry weights were evaluated at the end of the experiment, and the data are presented in Table 16. There were no significant differences in shoot dry weights among any of the treatments. Root dry weights increased slightly as N level increased from 6.25 ppm to 12.5 ppm. At N levels above 12.5 ppm, root dry weight decreased sharply. The difference between the highest level (50 ppm) was significantly less than the two lower levels (6.25 and 12.5 ppm), but not with 25 ppm N ($P = 0.03$). The comparison of the means is shown in Table 16. The root dry weights were also highly correlated with shoot dry weights ($r = 0.823$, $P = 0.01$).

5. Elemental Composition

Although ANOVA was not performed on the treatment effects on elemental composition of leaf tissues, the percent composition of N, P, K, Mg, S, and Si appeared to show the following relationship: percent N, P, K, Mg, and S content in the tissue seemed to increase with increase in N levels. The difference between the two lower N levels was quite negligible but was noticeably more marked above the 12.5 ppm N level. On the other hand, the percent Si in the leaf tissue appeared to have a negative response to N treatments, i.e., it decreased with increase in N levels.

B. K Treatments

The overall mean values of the effects of increasing K levels on visual ratings, clipping dry weights, and chlorophyll contents are presented in Tables 17 and 18. Varying levels of K within the range studied (7.5 to 60 ppm) did not produce differences in visual ratings, shoot dry weights, and root dry weights (Table 18). Clipping dry weight was significantly lower at 15 ppm than at 7.5 and 60 ppm, but not from 30 ppm. Chlorophyll content was higher at 15 ppm than any other level. Correlation between K treatments and visual ratings, clipping dry weights, chlorophyll contents, and root dry weights appeared not to be significant.

1. Visual Ratings

Weekly visual ratings did not indicate any significant difference with varying levels of K except at the last (eighth) week of the experiment.

At the 15 ppm visual rating value was highest (4.23) whereas visual ratings for 7.5, 50, and 60 ppm K were 4.01, 4.00, and 3.94 respectively (Table 18).

2. Clipping Dry Weights

The effects of K on clipping dry weights measured on a weekly basis were not significant. However, the overall mean effects for the eighth week period showed significant difference at 5% level. Significantly lower clipping dry weight was produced with 15 ppm K than with 7.5 or 60 ppm.

3. Chlorophyll Contents

The 15 ppm K level consistently resulted in the highest chlorophyll content value at all harvests when there were significant differences. Differences in chlorophyll contents in response to K treatments were observed in the second week of the experiment, and from the sixth week to the termination of the experiment. As expected, the overall mean of chlorophyll content effects were also significant. The association of chlorophyll content with K levels indicated that chlorophyll content increases as K level increases from 7.5 to 15 ppm.

Chlorophyll content values decrease as K levels increased above 15 ppm.

4. Elemental Composition

As in N treatments, ANOVA was not performed on the effects of K levels on elemental composition. Nevertheless, N contents appeared to increase when K levels increased from 7.5 to 15 ppm as in the case of chlorophyll content and decreased above the 15 ppm level. Influence of K on the %P, %S, and %Si appeared to be negligible. As expected, %K increased with increasing K levels. On the other hand, the relationship of K levels with %Mg appeared to be inverse.

C. Interactions between N and K Levels

The effects of N and K combination treatments on visual ratings, clipping dry weights, and chlorophyll contents are summarised as mean values in Table 19, and on shoot dry weights and root dry weights in Table 20. Visual ratings and shoot dry weights did not show significant interaction effects whereas clipping dry weight, chlorophyll content, and root dry weight effects were highly significant ($P = 0.01$).

1. Clipping Dry Weights

The effects of each level of K was not consistent and depended on the N level that it was applied with. There were no′difference in clipping dry weights due to different K levels at 6.25 and 12.5 ppm N but there were differences at 25 and 50 ppm (Figure 1). The differences in clipping weights between different combinations of N and K ranged from 0.01 g to 0.15 g. As discussed later, good quality turf resulted in the production of 0.75 g of clipping dry weights. Thus the combination treatment which produced somewhat similar yield (0.74 g) was 12.5 ppm N, and 15 ppm K.

2. Chlorophyll Contents

The highest chlorophyll content was obtained with the highest N level (50 ppm), and a lower K level of 15 ppm, while the lowest chlorophyll content was at 6.25 ppm N, and 60 ppm K. As in clipping dry weights, the influence of K levels did not follow the same patterm for each level of N. As shown in Figure 2, K had no effect on chlorophyll content at 50 ppm N. K levels above 15 ppm resulted in lower chlorophyll contents at 12.5 and 25 ppm N. Chlorophyll content increased with

50 ppm K, then decreased with 60 ppm K and 6.25 ppm N.

3. Root Dry Weights

The effect of N and K on root dry weights measured at the end of the experiment was highly significant (P = 0.01). Generally, the two lower N levels of 6.25 and 12.5 ppm in combination with different K levels produced higher root dry weight values although the lowest root dry weight was also observed when 6.25 ppm N was applied in combination with 30 ppm K. The highest N level of 50 ppm generally produced less root dry weight (less than 10 g). Root dry weights ranged from 7.61 to 12.19 g with the highest value from the combination of 12.5 ppm N, and 7.5 ppm K, and the lowest from 6.25 ppm N and 30 ppm K.

Table 15

MAIN EFFECTS OF N ON VARIOUS GROWTH PARAMETERS OF CARPETGRASS. AVERAGE OF FOUR REPLICATION, FOUR K LEVELS, AND EIGHT WEEKLY HARVEST PERIODS.

N levels (ppm)	VR^x	CW^y	CC^z	%N	%P	%K	%Mg	%S	%Si
6.25	3.77a	0.58a	3.75a	2.14	0.28	1.90	0.22	0.17	0.55
12.50	4.10b	0.78b	4.13b	2.24	0.29	1.93	0.22	0.18	0.50
25.00	4.56c	0.99c	4.75c	2.67	0.32	2.17	0.28	0.24	0.48
50.00	4.99d	1.23d	5.73d	3.29	0.38	2.49	0.40	0.34	0.42

For each column, means for treatment effects followed by the same letter do not differ significantly (BLSD = 0.05). ANOVA was not performed for the elemental contents because there was no replication.

x - VR = Visual Ratings on scale of 1 - 5 with 1 poorest and 5 best

y - CW = Clipping Dry Weights (g/pot)

z - CC = Chlorophyll Contents (mg/g dry wt)

Table 16

MAIN EFFECTS OF N LEVELS ON VARIOUS GROWTH PARAMETERS OF CARPETGRASS AT THE EIGHTH WEEK OF TREATMENT. AVERAGE OF FOUR REPLICATIONS AND FOUR K LEVELS.

N levels (ppm)	VR[v]	CW[w]	CC[x]	SW[y]	RW[z]	%N	%P	%K	%Mg	%S	%Si
6.25	3.21a	0.39a	3.31a	14.40	10.15a	2.07	0.29	1.81	0.20	0.15	0.55
12.50	3.64b	0.64b	4.02b	15.98	10.42a	2.26	0.32	1.95	0.21	0.18	0.46
25.00	4.32c	0.88c	4.83c	16.10	9.82ab	2.77	0.37	2.26	0.30	0.26	0.39
50.00	5.00d	1.08d	5.78d	15.91	8.63b	3.57	0.44	2.68	0.46	0.40	0.36

For each column, means for treatment effects followed by the same letter do not differ significantly (BLSD = 0.05). Data for elemental contents were obtained by combining samples from four replications.

v - VR = Visual Ratings on scale of 1 - 5 with 1 poorest and 5 best

w - CW = Clipping Dry Weights (g/pot)

x - CC = Chlorophyll Contents (mg/g dry wt)

y - SW = Shoot Dry Weights (g/pot)

z - RW = Root Dry Weights (g/pot)

Table 17

MAIN EFFECTS OF K LEVELS ON VARIOUS GROWTH PARAMETERS OF CARPETGRASS. AVERAGE OF FOUR REPLICATIONS, FOUR N LEVELS, AND EIGHT HARVEST PERIODS.

K levels (ppm)	VR[x]	CW[y]	CC[z]	%N	%P	%K	%Mg	%S	%Si
7.5	4.33a	0.93a	4.56a	2.52	0.31	1.88	0.31	0.24	0.47
15.0	4.38a	0.85b	4.78b	2.68	0.33	2.19	0.30	0.25	0.49
30.0	4.36a	0.88ab	4.54a	2.61	0.32	2.18	0.26	0.22	0.50
60.0	4.34a	0.93a	4.47a	2.53	0.32	2.24	0.25	0.21	0.48

For each column, means for treatment effects followed by the same letter do not differ significantly (BLSD = 0.05). ANOVA was not performed for the elemental contents because there was no replication.

x - VR = Visual Ratings on scale of 1 - 5 with 1 poorest and 5 best

y - CW = Clipping Dry Weights (g/pot)

z - CC = Chlorophyll Contents (mg/g dry wt)

Table 18

MAIN EFFECTS OF K LEVELS ON VARIOUS GROWTH PARAMETERS OF CARPETGRASS AT THE EIGHTH WEEK OF TREATMENT. AVERAGE OF FOUR REPLICATIONS AND FOUR N LEVELS.

K levels (ppm)	VR[v]	CW[w]	CC[x]	SW[y]	RW[z]	%N	%P	%K	%Mg	%S	%Si
7.5	4.01a	0.74a	4.44ab	16.31a	10.45a	2.59	0.35	1.87	0.38	0.27	0.42
15.0	4.23a	0.96a	4.74b	14.63a	9.25a	2.68	0.36	2.04	0.31	0.27	0.50
30.0	4.00a	0.77a	4.45ab	15.57a	9.45a	2.76	0.35	2.25	0.27	0.23	0.44
60.00	3.94a	0.81a	4.33b	16.39a	9.88a	2.63	0.35	2.33	0.25	0.21	0.42

For each column, means for treatment effects followed by the same letter do not differ significantly (BLSD = 0.05). Data for elemental contents were obtained by combining samples from four replications.

v - VR = Visual Ratings on scale of 1 - 5 with 1 poorest and 5 best

w - CW = Clipping Dry Weights (g/pot)

x - CC = Chlorophyll Contents (mg/g dry wt)

y - SW = Shoot Dry Weights (g/pot)

z - RW = Root Dry Weights (g/pot)

Table 19

EFFECTS OF DIFFERENT N AND K LEVELS ON VARIOUS GROWTH PARAMETERS OF CARPETGRASS OVER EIGHT HARVEST PERIODS. AVERAGE OF FOUR REPLICATIONS.

N level (ppm)	K level (ppm)	VR[x]	CW[y]	CC[z]	%N	%P	%K	%Mg	%S	%Si
6.25	7.5	3.69	0.60ab	3.63ab	2.07	0.27	1.74	0.20	0.16	0.53
6.25	15.0	3.79	0.59a	3.77abc	2.11	0.28	1.90	0.23	0.18	0.55
6.25	30.0	3.90	0.51a	4.00cd	2.33	0.29	2.04	0.24	0.18	0.59
6.25	60.0	3.69	0.62abc	3.59a	2.04	0.27	1.90	0.20	0.15	0.53
12.50	7.5	4.07	0.85de	4.23d	2.19	0.29	1.80	0.23	0.18	0.50
12.50	15.0	4.18	0.74bcd	4.50e	2.37	0.31	2.13	0.24	0.19	0.49
12.50	30.0	4.05	0.77cd	3.84bc	2.18	0.28	1.85	0.21	0.16	0.52
12.50	60.0	4.11	0.76cd	3.96c	2.22	0.29	1.95	0.21	0.17	0.50
25.00	7.5	4.58	0.99efg	4.77fg	2.61	0.32	1.93	0.31	0.26	0.46
25.00	15.0	4.60	0.93e	4.97g	2.90	0.34	2.34	0.30	0.27	0.49
25.00	30.0	4.52	1.09gh	4.59ef	2.49	0.31	2.08	0.24	0.21	0.48
25.00	60.0	4.54	0.95ef	4.68ef	2.66	0.32	2.33	0.25	0.21	0.48
50.00	7.5	5.00	1.27ij	5.67hi	3.21	0.37	2.06	0.49	0.37	0.40
50.00	15.0	4.97	1.14ghi	5.89i	3.32	0.39	2.37	0.44	0.35	0.42
50.00	30.0	4.99	1.14hi	5.72hi	3.42	0.38	2.37	0.35	0.33	0.42
50.00	60.0	5.00	1.40j	5.64h	3.19	0.38	2.79	0.33	0.30	0.42

For each column, means for treatment effects followed by the same letter do not differ significantly (BLSD = 0.05). Each week's data for elemental contents were obtained by combining samples from four replications.

x - VR = Visual Ratings on scale of 1 to 5 with 1 poorest and 5 best

y - CW = Clipping Dry Weights (g/pot)

z - CC = Chlorophyll Contents (mg/g dry wt)

Table 20

EFFECTS OF DIFFERENT N AND K LEVELS ON VARIOUS GROWTH PARAMETERS OF CARPETGRASS AT THE EIGHTH WEEK OF TREATMENTS. AVERAGE OF FOUR REPLICATIONS.

N level (ppm)	K level (ppm)	VR[v]	CW[w]	CC[x]	SW[y]	RW[z]	%N	%P	%K	%Mg	%S	%Si
6.25	7.5	3.00	0.40	3.12	15.19	10.95abc	1.98	0.28	1.64	0.19	0.14	0.49
6.25	15.0	3.33	0.38	3.23	14.67	11.52ab	2.00	0.29	1.82	0.22	0.16	0.64
6.25	30.0	3.38	0.38	3.80	12.39	7.61e	2.34	0.30	1.98	0.23	0.17	0.57
6.25	60.0	3.13	0.41	3.11	15.34	10.52abcd	1.96	0.28	1.81	0.17	0.13	0.48
12.50	7.5	3.58	0.68	4.04	16.79	12.19a	2.15	0.32	1.76	0.21	0.17	0.45
12.50	15.0	4.00	0.64	4.56	13.31	8.25cde	2.41	0.34	2.25	0.24	0.21	0.53
12.50	30.0	3.50	0.62	3.72	16.86	10.88abcd	2.22	0.30	1.85	0.20	0.16	0.40
12.50	60.0	3.50	0.64	3.78	16.98	10.38abcde	2.24	0.30	1.92	0.20	0.16	0.47
25.00	7.5	4.45	0.84	4.85	16.03	9.48abcde	2.76	0.37	1.99	0.36	0.31	0.37
25.00	15.0	4.58	0.81	5.31	15.99	9.19bcde	2.92	0.38	2.44	0.31	0.29	0.41
25.00	30.0	4.13	1.02	4.49	18.53	11.65ab	2.54	0.34	2.09	0.24	0.21	0.42
25.00	60.0	4.13	0.88	4.87	15.85	8.95bcde	2.86	0.38	2.53	0.27	0.23	0.37
50.00	7.5	5.00	1.03	5.75	17.22	9.17bcde	3.47	0.41	2.09	0.59	0.46	0.36
50.00	15.0	5.00	0.95	6.04	14.36	8.04de	3.60	0.45	2.50	0.52	0.42	0.41
50.00	30.0	5.00	1.06	5.79	14.50	7.64e	3.77	0.45	3.07	0.40	0.38	0.35
50.00	60.0	5.00	1.29	5.56	17.38	9.66abcde	3.45	0.43	3.07	0.31	0.34	0.32

For each column, means for treatment effects followed by the same letter do not differ significantly (BLSD = 0.05). Data for elemental contents were obtained by combining samples from four replications.

v - VR = Visual Ratings on scale of 1 to 5 with 1 poorest and 5 best

w - CW = Clipping Dry Weights (g/pot)

x - CC = Chlorophyll Contents (mg/g dry wt)

y - SW = Shoot Dry Weights (g/pot)

z - RW = Root Dry Weights (g/pot)

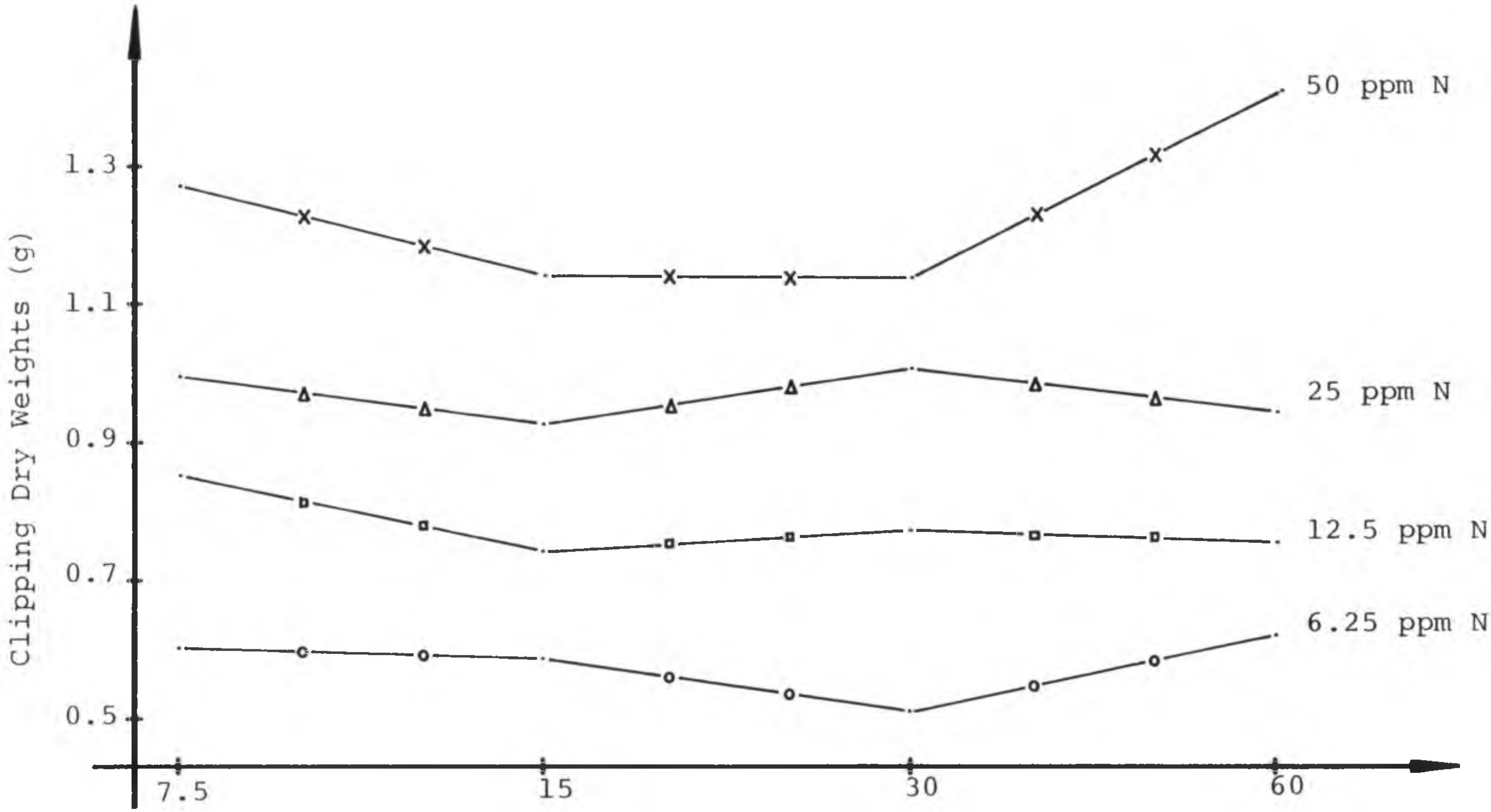

Figure 1. Effects of N and K on Clipping Dry Weights of Carpetgrass. Average of eight harvest dates and four replications.

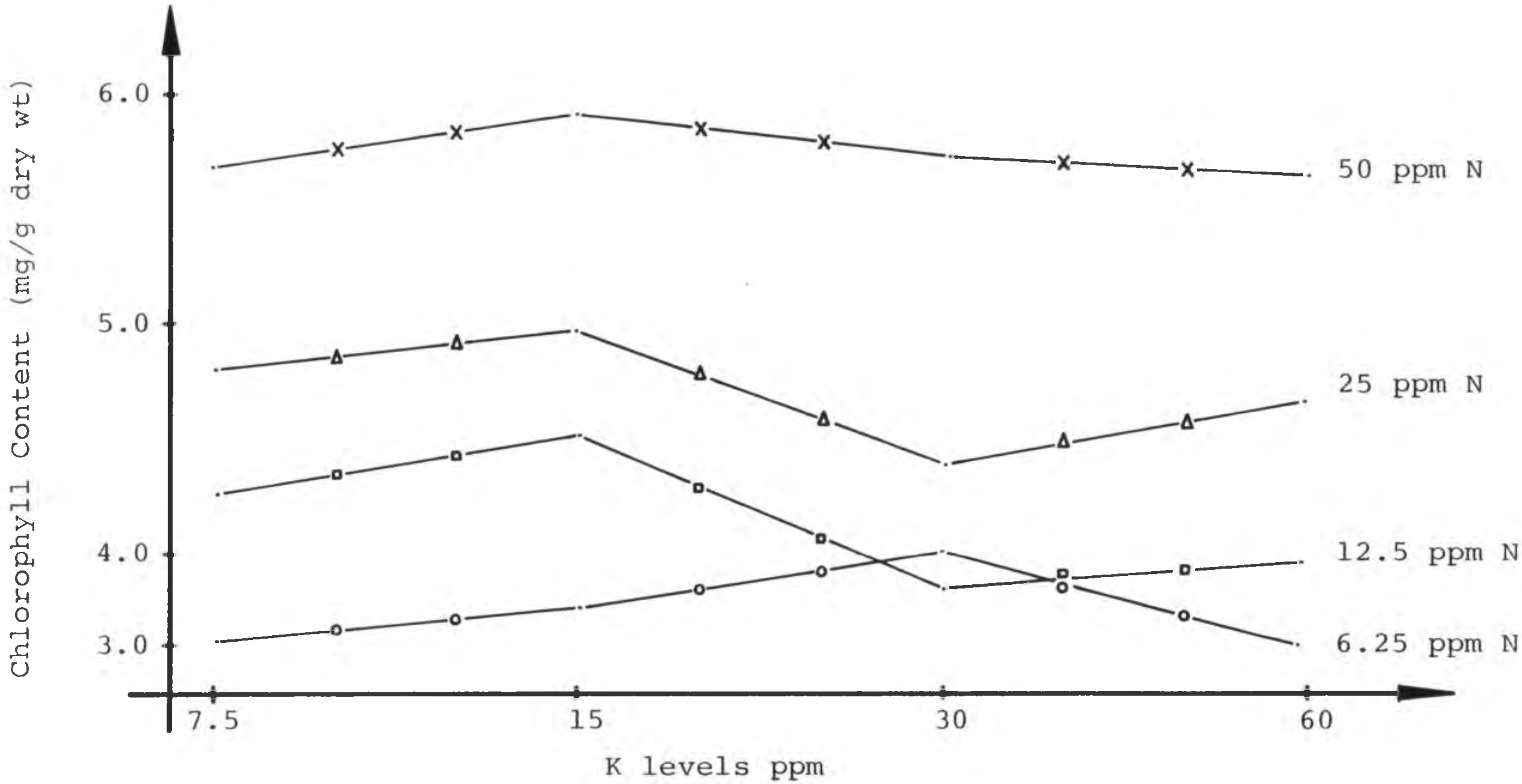

Figure 2. Effects of N and K on Chlorophyll Contents of Carpetgrass. Average of eight harvest dates and four replications.

Comparison of Parameters (Experiment II)

A matrix of the correlations between treatments of nitrogen and potassium with the growth evaluation parameters of visual ratings, clipping dry weights, chlorophyll contents, shoot dry weights, and root dry weights are presented in Table 21. Correlations were significant at P = 0.05.

1. Visual ratings and other growth parameters

A highly positive correlation existed between visual ratings and both clipping dry weights and chlorophyll contents whereas a negative relation was demonstrated between visual ratings and root dry weights. Visual ratings were not correlated with shoot dry weights.

2. Clipping dry weights and chlorophyll contents, shoot dry weights and root dry weights

Clipping dry weights were positively correlated with both chlorophyll contents and shoot dry weights. No correlation was seen between clipping dry weights and root dry weights.

3. Chlorophyll contents and shoot dry weights, and root dry weights

A negative correlation was seen between chlorophyll contents and root dry weights but none between chlorophyll contents and shoot dry weights.

4. Shoot dry weights and root dry weights

Shoot dry weights were positively correlated with root dry weights.

Table 21

CORRELATION MATRIX - EXPERIMENT II

	VR[v]	CW[w]	CC[x]	SW[y]	RW[z]
VR	1.000	0.746*	0.641*	0.012	0.367*
CW	0.746*	1.000	0.465*	0.430*	0.066
CC	0.641*	0.465*	1.000	0.017	-0.511*
SW	0.012	0.430*	0.017	1.000	0.823*
RW	0.367*	0.066	-0.511*	0.823*	1.000

* Significant correlation at P = 0.05

v - VR = Visual Ratings on scale of
1 - 5 with 1 poorest and 5 best

w - CW = Clipping Dry Weights (g/pot)

x - CC = Chlorophyll Contents (mg/g dry wt)

512 Observations

y - SW = Shoot Dry Weights (g/pot)

z - RW = Root Dry Weights (g/pot)

64 Observations

CHAPTER V

DISCUSSION AND CONCLUSION

Experiment I: Mowing and N fertilization on six warm season turfgrasses.

The objective for conducting this experiment was to determine the effects of mowing heights and N fertilization on warm season turfgrasses.

Mowing and fertilization are two cultural practices that have to be carried out regularly. However, the decision on how high a turfgrass should be cut without deterioration of quality, is one of the primary concerns of all turfgrass managers. Generally speaking, mowing the turfgrass higher would result in less costly maintenance than at lower cuts. Thus within the recommended range of mowing heights for each species, the question of what difference, if any, would exist in turfgrass quality between the low and high recommended heights is raised. Likewise, the same question would arise with respect to fertilization.

The general relationship of decreased top growth with decreasing mowing height with cool season grasses has been well documented by numerous researchers, although exceptions to the rule have also been shown, especially at low N level (Adams et al 1974). In our experiment, low mowing height reduced top growth in bermudagrass, but St. Augustinegrass and carpetgrass responded reciprocally to low cutting heights (Tables 7 and 8). Although this reciprocal relationship normally occurred at low N levels, an examination of the tissue N content revealed that it was adequate in these turfgrasses. The amount of top growth has been associated with carbohydrate contents in the plant (Adams et al 1974). It would therefore appear that even at low mowing heights there was sufficient carbohydrates in St. Augustinegrass and carpetgrass for leaf production and continued growth without slowing down the rate. Plausible sources of these carbohydrates are:

1) In spite of the recommended low mowing heights used, they should not reduce the photosynthetic surfaces much as these were "recommended low". The non-significant response of centipedegrass (Table 7) was in all probability due to this factor, as a rather thick mat was evident after each mowing operation. Biran et al (1981) noted that C_4 turfgrasses only

responded temporarily to high mowing by the production of more dry matter. They too found that centipedegrass, amongst other species studied, was unaffected by mowing treatments after a time. This was attributed to the thick thatch often associated with high mowing heights on warm season grasses which does not contribute to photosynthetic activities. Another factor is that the recommended mowing heights were generally determined on mainland United States between the latitude of 25 - 37°N. However, Hawaii is at latitude 22°N, has high light intensity, and no continental effect. As a result, the increase in leaf area index associated with high mowing was not evident with time. By the same token, this also explained the decreasing effects of mowing heights in carpetgrass where responses were observed at the early part of the experiment, and not in the final week.

ii) Even when a larger total photosynthetic area was removed at low mowing heights, there was still sufficient carbohydrates for continued top growth especially when other essential nutrients such as nitrogen was not a limiting factor. Leaf tissue analysis showed an adequate N content in these turfgrasses (Table 7). Furthermore, being C_4 plants (Krans et al 1979) they are very efficient in photosynthesis. In the unreplicated zoysiagrass plots, the nitrogen content in leaf tissues was somewhat low (about 2.5%) from the plots mowed low (Table 7). Thus, even though a thick mat remained after each mowing, greater top growth was obtained at the low cutting height. This was similarly observed by Adams et al (1974) in cultivars of *Lolium perenne* L., and *Poa pratensis* L. However, the significance of this effect has to be determined further in view that there was no replication for this species in this experiment.

iii) As the experiment was conducted for a fairly short duration of three months, the carbohydrates reserves may not have been depleted, especially when the lowest mowing heights were not low enough to reduce the photosynthetic area significantly. Perhaps if treatments were given over a longer period, resulting in the depletion of the carbohydrates store, effects may have been different.

The reciprocal response of St. Augustinegrass to mowing heights could also be due partially to the carbohydrates stored in the thick stolons and roots. The photosynthetic surfaces were much reduced when mowed at the recommended low height of 3.75 cm. Frequently, stolons become exposed after each mowing operation. As top growth takes precedence over root growth (Adams et al 1974), in a situation when photosynthesis is reduced, whatever photosynthates and carbohydrates that are available would be used for shoot growth. The data on the clipping dry weights and root depths in St. Augustinegrass (Table 7) seemed to support this. At low cutting height, higher clipping dry weight, and shorter roots were observed, whereas, at high mowing height, the clipping dry weight was lower and roots deeper. Low mowing heights have been known to encourage shoot density (Beard 1973, and Adams et al 1974). Denser shoots and shorter internodes were observed in St. Augustinegrass which was mowed low.

Mowing heights also influence the visual ratings and chlorophyll content of the turfgrass, in that variable amounts of photosynthetic surfaces are removed depending on the height at which the turfgrass is mowed. This is supported by the high correlations between visual ratings and mowing heights. The coefficient of correlation for both bermudagrass and centipedegrass was -1.000 and both carpetgrass and St. Augustinegrass had positive correlation with r values of 0.953 and 0.956 respectively. The negatively correlation between mowing heights and chlorophyll contents was also significant in bermudagrass and centipedegrass (Table 7). These results concurred with the high visual ratings and chlorophyll contents of the plots mowed low in bermudagrass and centipedegrass. The reverse was true for carpetgrass and St. Augustinegrass, i.e., lower visual ratings and chlorophyll contents were associated with the low mowing heights, and higher values with high mowing heights (Table 7). This relationship was most likely attributed to the difference in leaf texture, shoot density, and growth habit of the grasses. Bermudagrass and carpetgrass have finer, denser leaves with shorter internodes than St. Augustinegrass and carpetgrass. The leaves of bermudagrass and centipedegrass tend to be displayed on a more horizontal plane than those of carpetgrass and St. Augustinegrass. Total leaf area index is much greater for bermudagrass and centipedegrass. For this reason, a greater amount of photosynthetic surface is left after close mowing. Although higher clipping dry weights were associated with the plots mowed low in carpetgrass (Table 8), it would imply that although the regrowth was great, it was, nevertheless, not as efficient as the plots with high mowing treatments. This further suggests that with time, the response of this turfgrass to high mowing heights with respect to clipping dry weights may change.

The direct relationship of root depths with mowing heights was demonstrated in St. Augustinegrass. Although differences were not significant (P = 0.05) in the other species, the trend appeared to be consistent (Table 7). It has been reported that where competition for carbohydrate exists, the top growth would take precedent over that of roots (Adams et al 1974). Thus when mowing height was low, the demand for carbohydrates would result in the channelling of these to the top and the root growth would consequently slow down, and roots become shallower. As there was no response in top growth of centipedegrass, the insignificant difference was thus expected.

In view of the above, and under the conditions of the experiment, it would appear that the high mowing height would be preferred in all the four species studied. This is especially so for general purpose turf. Further, a high clipping dry weight is not necessarily associated with better quality grass, as it may indicate a luxuriant turf instead. This is not a desirable characteristic because the turfgrass would become puffy and succulent, more susceptible to diseases, and less wear tolerant.

Data from the single replication experiments on zoysiagrass and seashore paspalum (Table 7) seemed to agree with the high mowing height preference but this would have to be substantiated by further experimentation involving replications.

The effects of N fertilization on shoot and root growths are well known. Responses of centipedegrass (Table 9) firmly established the effectiveness of increasing top growth, measured by clipping dry weights and chlorophyll contents and depressed root growth in terms of root depths, with increasing N within the range applied. Tissue analysis data demonstrated clearly the increase in N in the tissue with increase in N fertilization in this turfgrass. Consequently, N being an important constituent of the chlorophyll molecule, would logically increase the chlorophyll content. This, in turn, influenced the increase in top growth, as evidenced by the significant increase in clipping dry weights. Furthermore, as demonstrated by other researchers, such as Adams et al (1974), and Watschke and Waddington (1974), N status in the tissue was responsible for the utilization of carbohydrates for top growth processes. Thus, with high N, more carbohydrates were used for top growth and consequently, less carbohydrates were channelled to the storage organs such as the roots and stems, and less growth occurred in these parts. Data from the experiment (Table 9) were in agreement with the notion that N was responsible for carbohydrate turnover in the plant. Hence, low N resulted in lower shoot growth and more root growth than high N. In the case of bermudagrass, higher clipping dry weights were collected from plots with low N treatment than with high N and no difference was observed in root depths of plots with low or high N levels. Although there was no significant difference at $P = 0.05$ there appeared to be a higher N content in the leaves from plots with low N than with high N. This could be responsible for high clipping dry weights in the plots which were mowed low. With the high variability observed, it could also be due to experimental error. Although root depths were affected by the level of N applied in St. Augustinegrass, no significant difference ($P = 0.05$) was observed in tissue N, chlorophyll content and clipping dry weights (Table 9). The source carbohydrate turnover as a result of higher N application, which caused a reduction in root depth could have been from the stolons and not the leaves. This would not be surprising in a turfgrass such as St. Augustinegrass which has extremely large stolons.

Experiments would have to be carried out to establish this. In the case of carpetgrass, increasing N levels did not contribute to differences in the growth parameters although tissue N increased (Table 9). As this is a low cultural intensive turfgrass, the maximum N requirement was probably attained at the low N level, and further increases brought no further changes in the growth responses. Within the range examined, the N content had not reached detrimental levels. This then confirmed the view that the relationship between dry tissue production in response to increased N levels was quadratic (Christians et al 1979).

The interaction effects of mowing heights and N levels were not significant for all parameters examined for carpetgrass, centipedegrass and St. Augustinegrass. This again could not be conclusive as the experiment was only conducted over a three month period and with time, the results may be different. The combination of low mowing height and low fertilization yielded the highest clipping dry weights for bermudagrass (Table 10). This was incongruent with the findings of other researchers (Adams et al 1974, Juska et al 1955, and Juska and Murray 1972) where high mowing height and high nitrogen level yielded the highest top growth. Because of the variations observed in the readings this datum could be due to experimental error. The amount of clipping dry weights associated with combinations of N applications were due to the balance between the carbohydrate contents and N content in the plant. At low mowing heights, more photosynthates were removed and less carbohydrates would be available. Many workers such as Adams et al (1974) found N was responsible for the carbohydrates turnover in turf. Similarly, Harrison (1931) stated that a point could be reached with increasing N where there would be carbohydrate starvation.

From the foregoing, it can be seen that both mowing heights and N can affect differential growth responses even within the recommended range. This reaction seemed to be brought about by the balance of carbohydrates and N status in the turfgrass. Under the conditions of the experiment, and based on the data collected so far, a combination of high mowing and low N appeared to produce acceptable good quality turf and reduce maintenance requirements. High mowing may also mean less frequent mowing resulting in further savings, especially for carpetgrass, centipedegrass, and St. Augustinegrass. This would certainly be a welcomed proposition to all turf managers, but it should be applied with caution and monitored, as frequency of mowing may affect growth responses. This is, however not recommended for bermudagrass as it is a very fast growing turf, and leaving the grass too long may result in an excessively high percentage of leaf area being removed at each mowing. In view of the short duration of the experiment, results may be different with time. As for zoysiagrass and seashore paspalum, further experimentation need to be carried out.

Variations in the data observed further points out the need to conduct the experiment over a longer period of time with more replications. It is felt that the method used in the collection of clippings in the field and the root depths measurement should be improved.

Experiment II: Response of carpetgrass to N - K Fertilization

The nutritional status which affects turfgrass quality is influenced by many interacting factors. Amongst them is the N-K fertilizer ratios. As carpetgrass requires low cultural intensity, the experiment was conducted to investigate the levels of N and K required to provide acceptable turf quality.

Data from the experiment (Tables 15 and 16) were consistent with the generalization that increasing N levels increased top growth and depressed root growth. The influence of N on color and physiological processes such as photosynthesis in turfgrass was manifested in the visual ratings, clipping dry weights and chlorophyll contents. Consistent with the findings of other workers (Synder and Schmidt 1974, Walker and Ward 1974), all parameters used to evaluate the above characteristics, were positively correlated with N fertilization, i.e., increasing N resulted in higher parameter values. As there was no plateau in the response (Table 16), it would therefore appear that the maximum N level at which growth responses occurred had not been reached within the range examined. However, since acceptable turf (as indicated by visual ratings above 3) was produced at levels below the highest used in this experiment, it would appear that carpetgrass does not require high N level to produce good quality turfgrass under the conditions of the experiment. This seems to be in agreement with the field experiment, where increasing N level applied to carpetgrass did not improve the growth response (Table 9), even though the N content was found to increase with N levels. In fact, further increases in N may become detrimental to carpetgrass by creating an imbalance between carbohydrate content and N content. In addition, in turfgrass management, it is not the objective to produce luxuriant turf, the disadvantages of which were mentioned earlier, thus excessive N above the requirement should be avoided as far as possible. Results of the glasshouse experiment (Table 15) showed that a fairly good quality turf could be reached under the conditions of the experiment, with N above the 12.5 ppm level without reaching the highest level of 50 ppm where the turf tends to become luxuriant.

The role of K in turfgrass has not been clearly understood although its importance is recognized. K has been found to increase clipping dry weights (Markland and Roberts 1967). However, the influence has also been reported to be inconsistent but significant effects with time had been reported (Waddington et al 1972). The findings of our experiment (Tables 17 and 18) were consistent with those of Waddington's. The influence of K was manifested in different parameters over the period. K effects on clipping dry weights were not seen until Week seven where there were significantly lower clipping dry weights at 15 ppm than the other levels of 7.5, 30 and 60 ppm. Although tissue analysis data were unreplicated, K content, nevertheless, appeared to increase with addition of K. The difference was most pronounced between the 7.5 and 15 ppm level. From our experiment, chlorophyll content seemed to imply that there was an optimum level above which K would become detrimental to chlorophyll synthesis in the plant. It would appear that the concept of "luxury" consumption which had been previously reported did not seem to apply to the chlorophyll synthesis in carpetgrass. This could most likely be attributed to the imbalance between K and other nutrient contents such as N. The important of N-K balance in influencing metabolism and hence growth has been reported by various workers such as Wagner (1967) and Christians et al (1979). A look at the nutrient contents showed that increasing K levels did not, however, influence the N content. This resulted in an imbalance of N-K if K was increased without increasing N application. Our data collected at week eight (Table 18) further supported this. The influence of K on visual ratings was similarly manifested in week eight. On the other hand, clipping dry weights effects yielded the lowest clipping dry weight at 15 ppm (Table 17). Further increase in K level increased clipping dry weights. In interpreting this result, it would appear that the data did, after all, support the "luxury" consumption concept in terms of clipping dry weight. In this case, the low chlorophyll content above 15 ppm could be attributed to the dilution factor in that the total leaf area was increased as K increased. Similar increase in growth with increase in K have been well established by many workers (Markland and Roberts 1967, Monroe et al 1979, and Robertson 1978). High K promotes thicker and tougher leaves, and hence, the increase in clipping dry weight. On the other hand, if the chlorophyll content remained constant, this could result in a lower chlorophyll content per unit weight of clippings, and hence, the low visual rating and chlorophyll content values at higher K application. The initial decrease in clipping dry weights at the lowest K level could be due to the synthesis of chlorophyll taking precedence to leaf growth at low level of K.

Chlorophyll content values above 5 mg/g dry weight in combination with different K levels were observed in all cases of 50 ppm N and the lowest values were those of 6.25 ppm N in combination with different K levels (Table 20). This could imply that chlorophyll synthesis was highly dependent on N which was expected, as it is part of the chlorophyll molecule. As expected, the N-K ratio would be grossly imbalanced when 6.25 ppm N combined with 60 ppm K resulting in an almost 1 : 1 N-K ratio as seen in the tissue analysis at week eight (Table 20). This yielded an extremely low chlorophyll content similar to that obtained with combination of 6.25 ppm N and 7.5 ppm K in which case K was deficient. The chlorophyll content was similar in the overall mean data which again reflected differences (Table 19). Except for the lowest N level, the highest chlorophyll content was observed with 15 ppm K at each N level, and above this level of K the chlorophyll content decreased. Similarly, below this level, chlorophyll content was lower. This again supported the notion that at low K, chlorophyll synthesis will take place at the expense of growth, and above 15 ppm the influence of K on chlorophyll appeared to cease, and any addition of K will be used in the growth processes which resulted in higher clipping dry weight but lower chlorophyll content per unit weight of clipping. Increase in N level then also increased the absolute value of these parameters but the response pattern remained essentially the same. At low N the highest chlorophyll content occurred at a higher K level of 30 ppm K. Christians et al (1979) similarly observed that at high K, less N was requried for maximum quality. This could be attributed to N being the limiting factor in the synthesis and additional K was needed probably in other physiological processes involved in either the chlorophyll synthesis or top growth. As K is known to influence rooting, the additional K did not appear to do so at this combination as shown by the very low root dry weight data observed. That tops grow at the expense of roots is again sbustantiated by examining the three parameters of chlorophyll contents, clipping dry weights, and root dry weights. The root dry weights and clipping dry weights were consistently lower, when chlorophyll content was highest. This would mean that at this stage, the N and K were channelled to chlorophyll synthesis and when nitrogen was increased, top growth in terms of clipping dry weight also increased, but not root growth. This effect is again consistent with the established relationship mentioned earlier.

Data from the experiment would indicate that under the conditions of the experiment, N at 6.25 ppm, and K at 7.5 ppm were too low for carpetgrass. Although at 50 ppm N, the visual ratings were consistently high for all combinations of K level, the turf was luxuriant and succulent, and root growth was comparatively low. These undesirable turf characteristic would therefore rule out this as being the ideal N level. As for the 12.5 ppm N level, visual rating was below the "good" quality level. Thus 25 ppm N would be the most reasonable to recommend. The recommended range would therefore fall between 25 ppm N and 15 ppm K, and 25 ppm N and 30 ppm K. If a greener turf is desired, the former would be preferred. If a more wear resistant turf is desired, the latter would be the choice as it would produce tougher leaves, more shoot growth as seen in the shoot dry weight, and a larger root system.

Evaluation of Parameters

The primary parameters of visual ratings, clipping dry weights and chlorophyll contents have been demonstrated in both the field and the glasshouse experiments to be reliable and consistent in demonstrating the condition of the turfgrass. Although bias could creep in visual rating, it was found to be highly correlated with other parameters and the turf conditions. In the field experiment, visual ratings were found to be negatively correlated with tissue N content in carpetgrass (Table 12). In this case, a low visual rating value could indicate that excessive nitrogen has been applied. In the glasshouse experiment, visual ratings were found to reflect even the conditions of roots in terms of root dry weight although no correlation was demonstrated with root depths in the field experiment. In the latter, it could be due to the numerous environmental factors interacting, or that the root depths do not reflect the total root system of the turfgrass. Visual ratings were also not correlated with shoot dry weights in the glasshouse experiment (Table 21). Perhaps this was due to the tendency of giving color a very high weighting by the rater. Nevertheless, inspite of these drawbacks, visual rating is a reliable method of evaluating the quality of turfgrass.

Clipping dry weights do give an indication of the vigor of the turfgrass. Excessive clipping dry weights may mean that the turfgrass is growing too luxuriantly and reduction in cultural practices such as nitrogen fertilization should be considered.

Analyses of chlorophyll content as in leaf nitrogen tissue content will of course give the status of these molecules and nutrient in the tissue. However, for routine purposes, the method can be laborious and costly and are suggested for use only periodically to serve as checks to the other evaluation parameters.

Thus for routine evaluation of turfgrass quality, visual ratings would suffice with support from clipping dry weights which could be taken at longer intervals and chlorophyll and tissue analysis be used only periodically.

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